

An Assessment of Geological Carbon Sequestration in the Illinois Basin— A Research Update

presented by
Robert J. Finley and the MGSC
Project Team



July 11, 2008
WPSC

Madison, Wisconsin



Midwest Geological
Sequestration Consortium
www.sequestration.org



Acknowledgements

- This work is being supported by the U.S. Department of Energy, Office of Fossil Energy, as part of the Regional Sequestration Partnerships Program, and by the Illinois Office of Coal Development (DCEO) through the Illinois Clean Coal Institute, under the **Midwest Geological Sequestration Consortium (MGSC)**
- The **MGSC** is a collaboration led by the geological surveys of Illinois, Indiana, and Kentucky

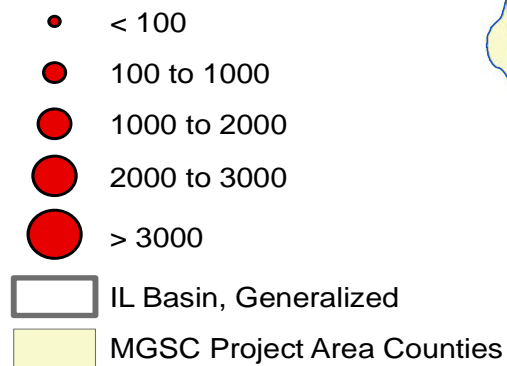


Outline

- Basic questions
- The big geologic picture - basin and reservoir
- Test site geology at Decatur, Illinois
- The physical set up at the test site
- What about the delivery of the CO₂?
- CO₂ – Where will it go and how do we check on it?
- Expected outcomes
- Challenges and problems
- Broader perspectives

Electric Generators Nameplate Capacity

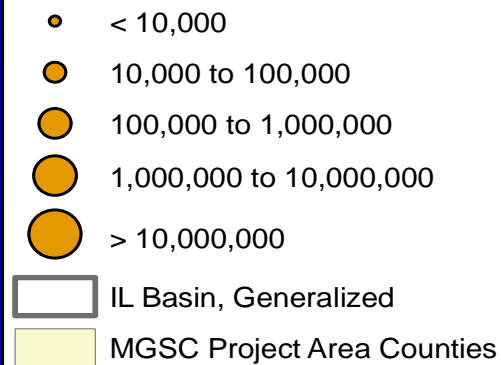
Electric Generators Nameplate Capacity (MW)



Source: US DOE Energy Information Administration 2002.

Electric Generators Annual CO₂ Emissions

Electric Generators Annual CO₂ emissions (Tons)



Source: US DOE Energy Information Administration 2002; US EPA Acid Rain 2002, EGRID 2000.

Basic questions

What did we do in Phase I?

- Assessed the Illinois Basin sedimentary reservoir framework for geological sequestration opportunities
- Developed data base and carried out basic mapping; assessed basin structure and saline reservoir geochemistry
- Defined sequestration resource in mature oil reservoirs, selected coal seams, and saline reservoirs
- Defined fixed sources and quantified emissions
- Carried out preliminary pipeline study
- Matched major sources and sinks as an illustration of capacity
- Developed education outreach materials and web site
- Compiled 478-page comprehensive report

What are we doing in Phase II?

- Completed single-well huff 'n puff injection test
- Developed coalbed methane injection site: four wells drilled and tested, test injection underway; 24-hour injection begins July 08
- Second EOR site identified; permit being sought
- Third EOR test site identified and other candidates being screened
- Phase II saline reservoir activities merged with Phase III; 2D seismic acquired; regional mapping completed

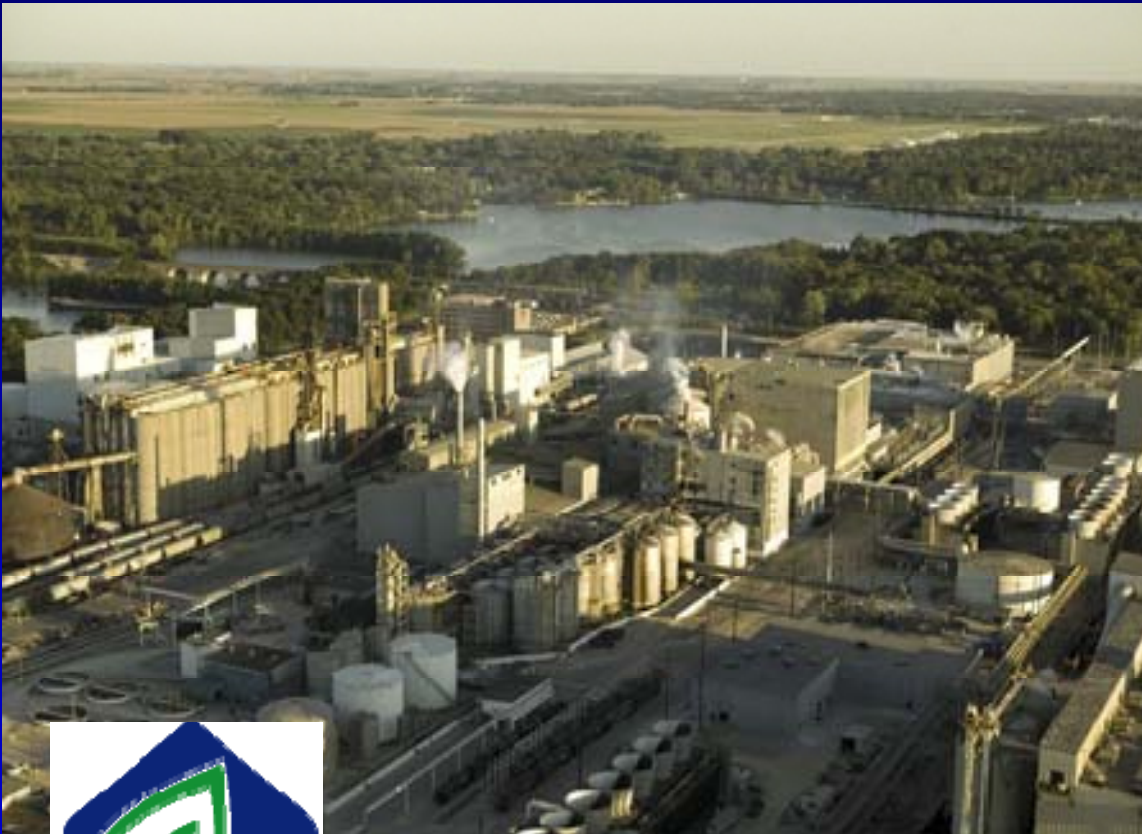
What are we doing in Phase III?

- A collaboration of the Archer Daniels Midland Company (ADM), the Midwest Geological Sequestration Consortium, Schlumberger Carbon Services, and other subcontractors plans to inject 1 million metric tons of carbon dioxide at a depth of 7,500 +/- ft to test geological carbon sequestration in a saline reservoir

Who are the major players?

- The Illinois State Geological Survey (ISGS) leads a research consortium of the Illinois, Indiana, and Kentucky geological surveys ([Midwest Geological Sequestration Consortium](#)), in place since 2003, to assess the geological carbon sequestration potential of the Illinois Basin
- National Energy Technology Laboratory, Office of Fossil Energy, leads for the [U.S. Department of Energy](#)
- [ADM](#) for CO₂ supply, permitting, site development, facilities engineering, CO₂ handling, outreach, and 24/7 operations
- [Schlumberger Carbon Services](#) will provide innovative technologies for well design, logging and completion, risk assessment, subsurface reservoir characterization, and geophysical monitoring

The Archer Daniels Midland Company



- Global company with \$44 billion sales, 27,000 employees
- Processes >500,000 bu corn/day at Decatur, IL
- Multiple products produced from corn

How did we get to this point?

- ISGS work from 2003-05 showed high potential in the Illinois Basin for geological carbon sequestration
- Small-scale CO₂ injection tests underway, 2005-09, mostly in oil fields
- DOE desired large-scale testing to begin before 2009; required major source of CO₂ and a suitable site in close proximity
- Discussions with ADM began in December 06
- Proposal submitted May 07; funded December 07

What is the Phase III project schedule?

- The project was funded December 18, 2007
- Baseline environmental activities to began spring 08
- Preliminary UIC permit hearing expected August 08
- Injection well drilling: November-December. 08; ~ 68 days to drill
- UIC Completion Report based on well data
- Final functional testing of compression, pipeline, and wellhead initiated in fall 09
- Injection would occur from December 2009- December 2012
- Verification wells would be drilled ~ summer 2009 and ~ summer 2012 (if second well funded)
- Environmental monitoring through December 2014

MGSC Partners and Advisors

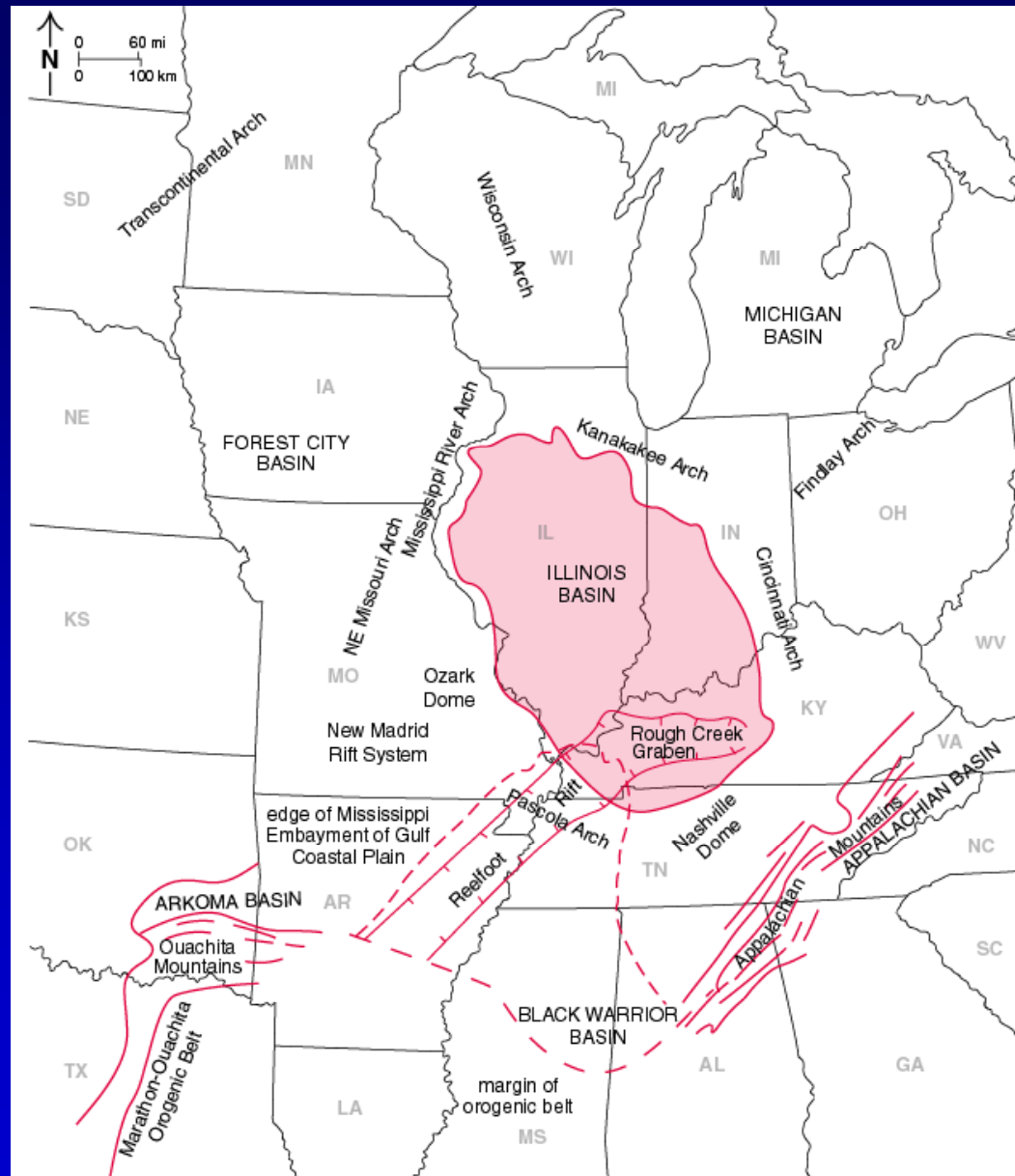
- Illinois State Geological Survey
- Indiana Geological Survey
- Kentucky Geological Survey
- Archer Daniels Midland Company
- Schlumberger Carbon Services
- Illinois Government Agencies:
 - Illinois Department of Natural Resources, Illinois Department of Commerce and Economic Opportunity – Office of Coal Development, Illinois Clean Coal Institute
- Trade Groups:
 - Illinois Corn Growers Association, EPRI, IOGCC, Illinois Oil and Gas Association, Kentucky Oil and Gas Association, Indiana Oil and Gas Association

MGSC Partners and Advisors (cont'd)

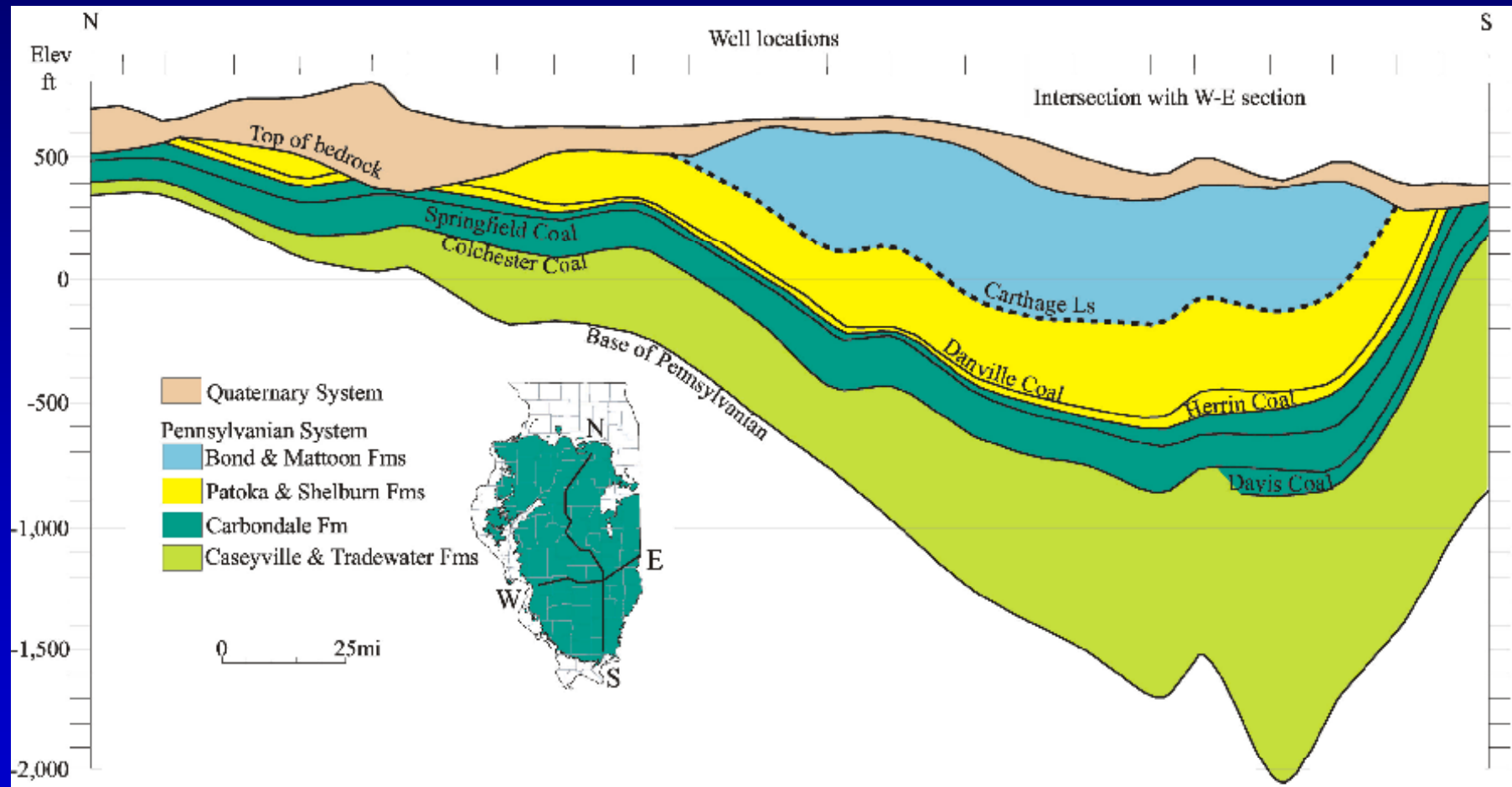
- Environmental NGOs:
 - Environmental Defense, Natural Resources Defense Council
- Industrial Partners:
 - Ameren, American Air Liquide, Aventine Renewable Resources, Biorecro LLC, Blue Source, British Petroleum, Carbon Storage Partners, The Cline Group, ConocoPhillips, Continental Carbonic Products, Drummond Coal, Duke Energy, Edison Mission Group, Indiana Gasification, LincolnLand Agri-Energy, Louisville Gas and Electric, Peabody Energy, Power Holdings, Praxair, Spectra Energy

The big geologic picture - basin and reservoir

Illinois Basin

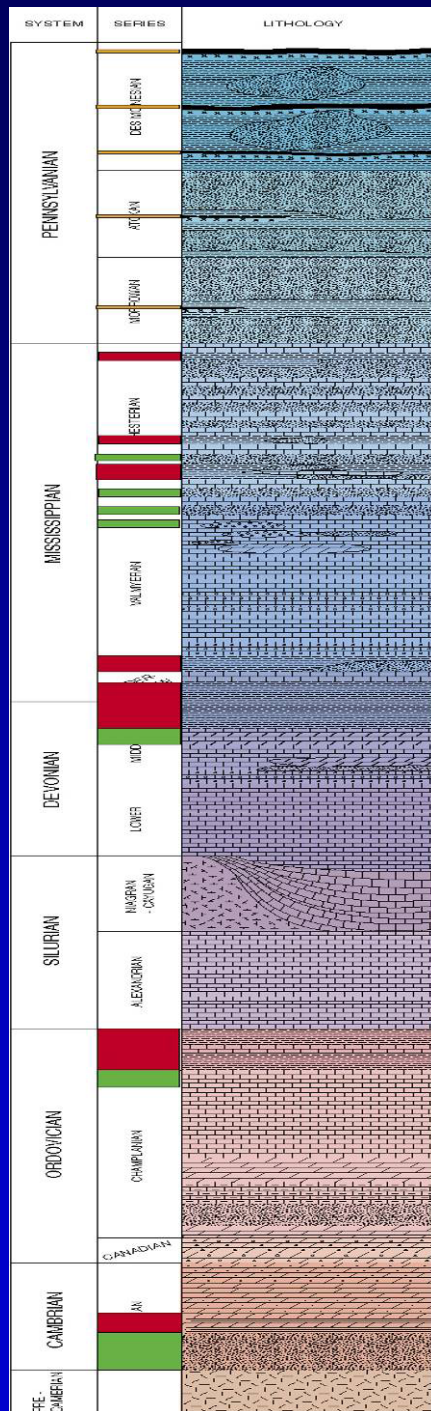


N-S Cross Section of Coal-bearing Strata in Illinois



By Christopher Korose, Jamie McBeth, and Colin Treworgy, ISGS

Illinois Basin Stratigraphic Column



Pennsylvanian coal seams

Mississippian sandstone and carbonate oil reservoirs

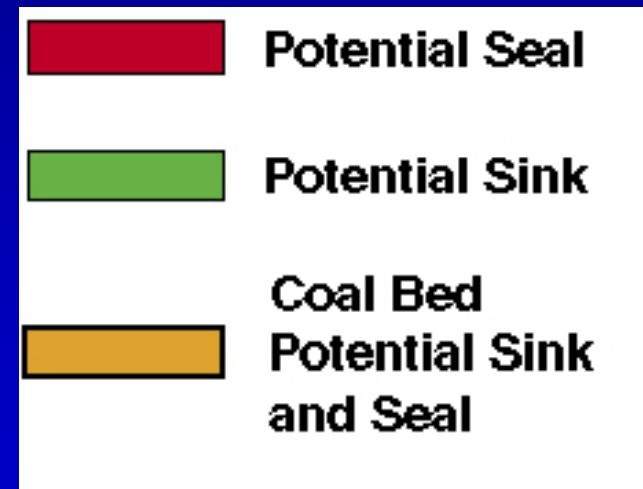
New Albany Shale

Maquoketa Shale

St. Peter Sandstone

Eau Claire Shale

Mt. Simon Sandstone



from Leetaru, 2004

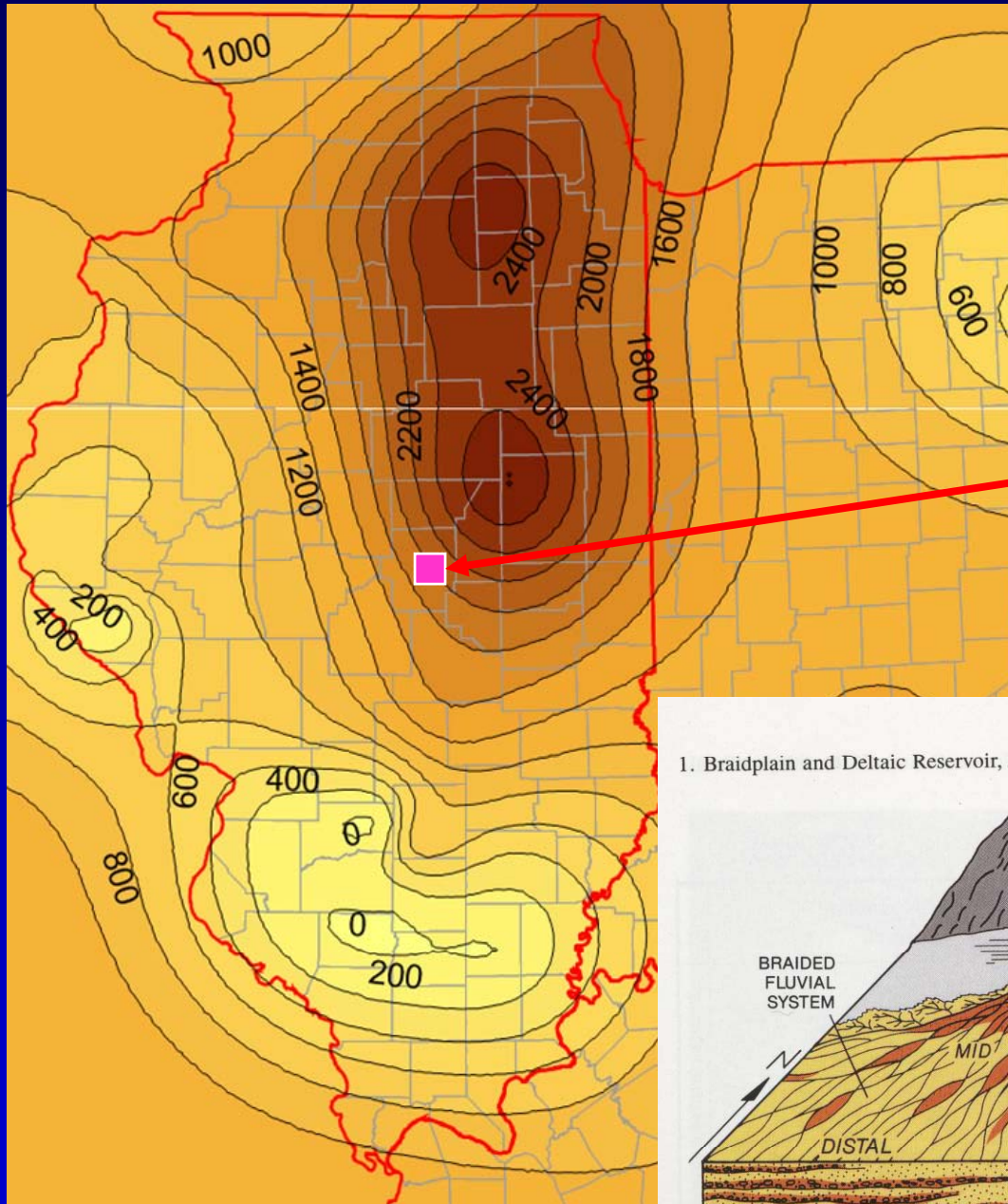
Sequestration Capacities*

- Seven major coal seams: 2.3-3.3 billion tonnes
 - 6.7 trillion ft³ incremental methane(?)
- Mature oil reservoirs: 140-440 million tonnes
 - 860-1,300 million barrels incremental oil
- St. Peter Sandstone: 1.6-6.4 billion tonnes
- Mt. Simon Sandstone: 27-109 billion tonnes

*DOE, 2007, Carbon Sequestration Atlas of the United States and Canada

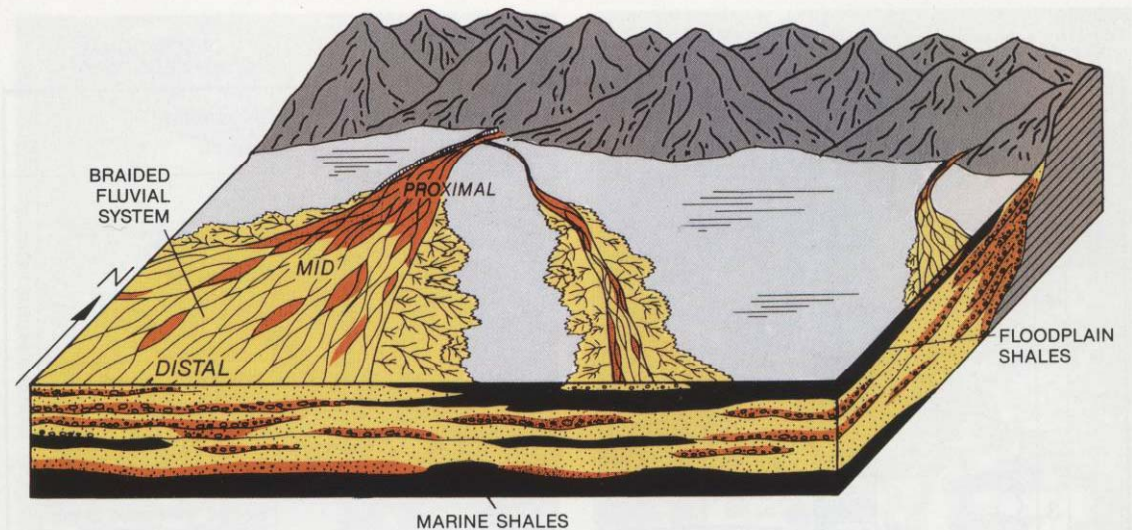
Mt. Simon Sandstone Isopach

ADM Site

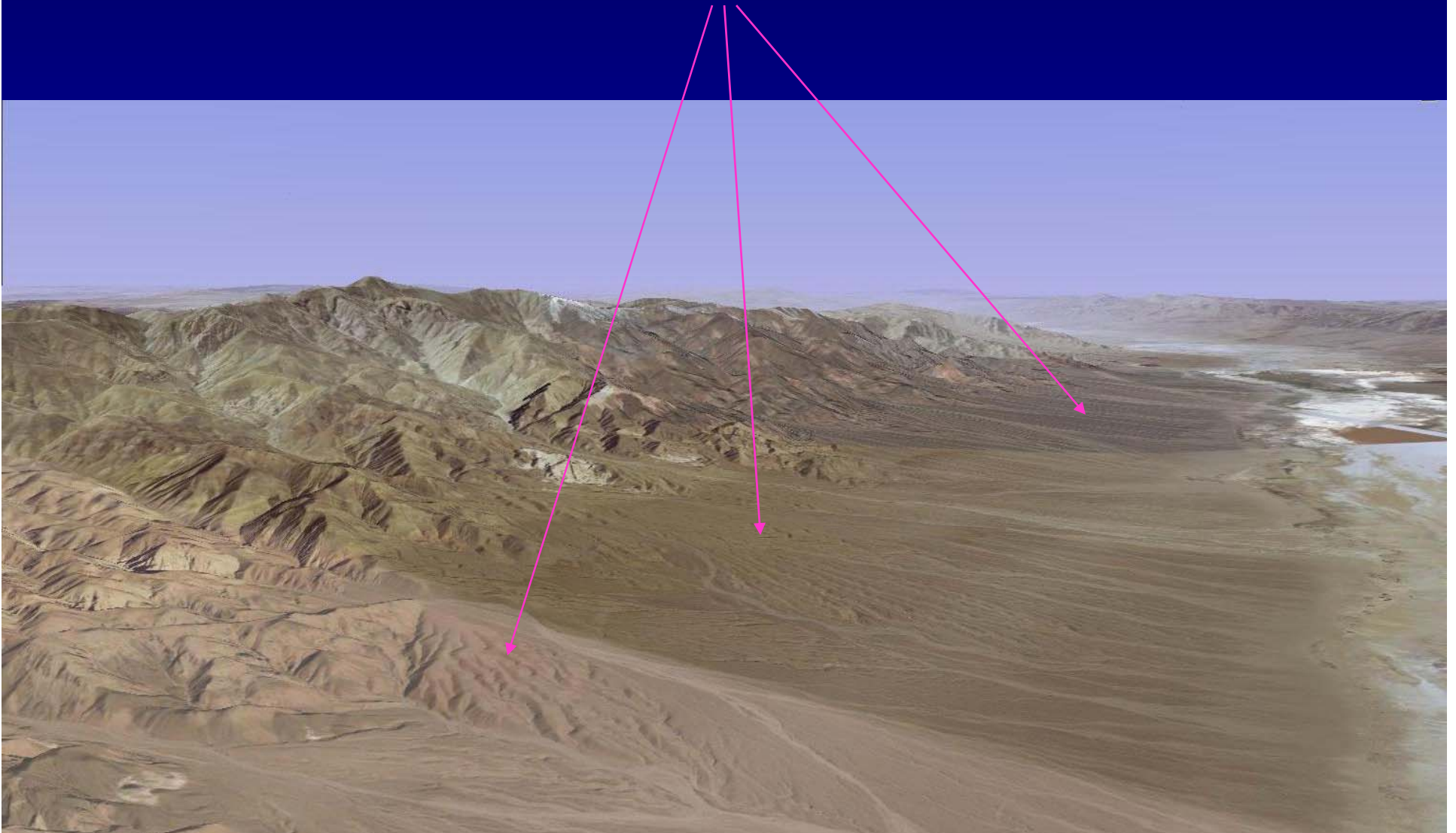


1. Braidplain and Deltaic Reservoir, Prudhoe Bay Field, Alaska

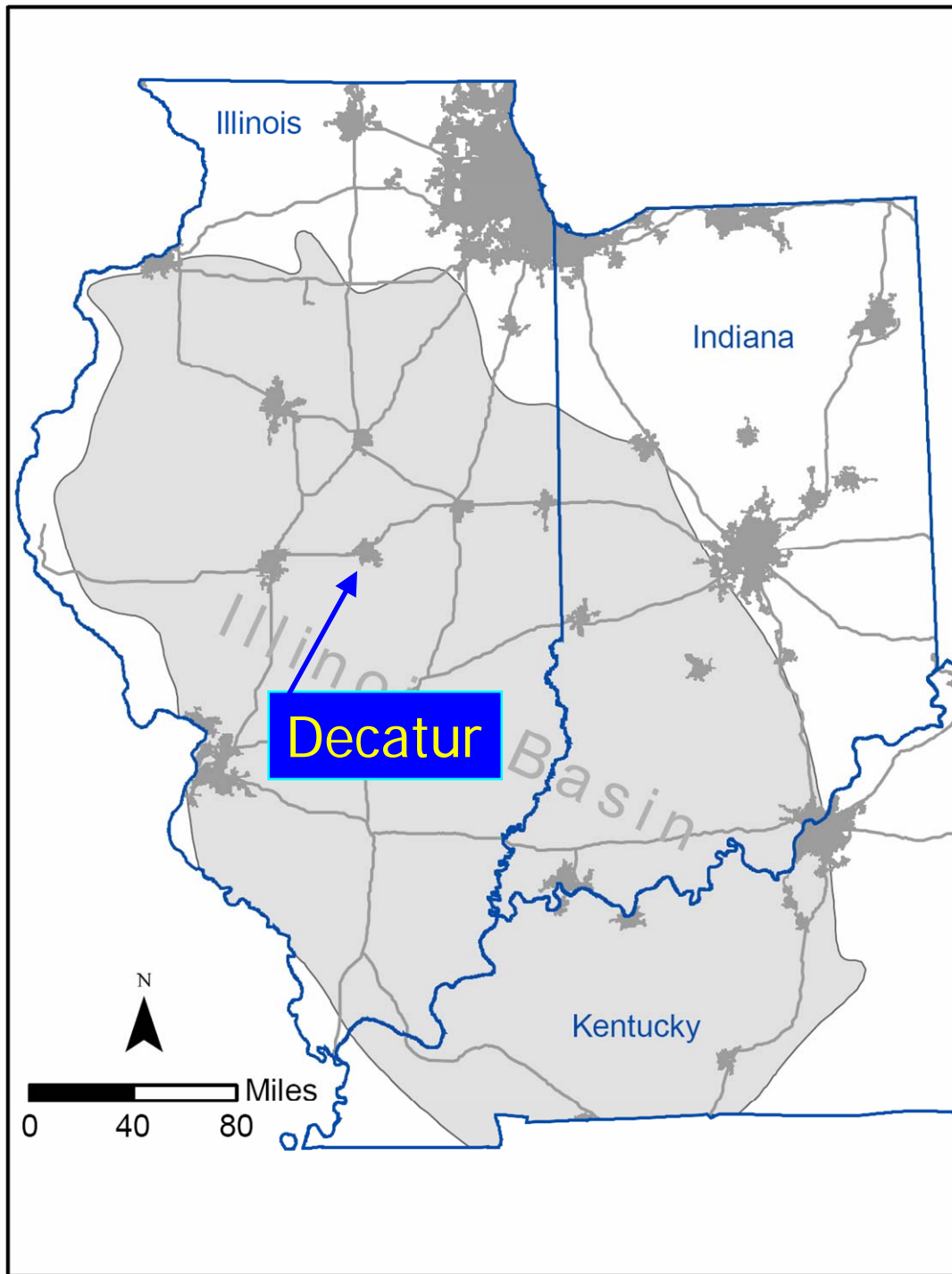
13



A Model for Mt. Simon Sandstone Deposition: Alluvial Fans in Death Valley



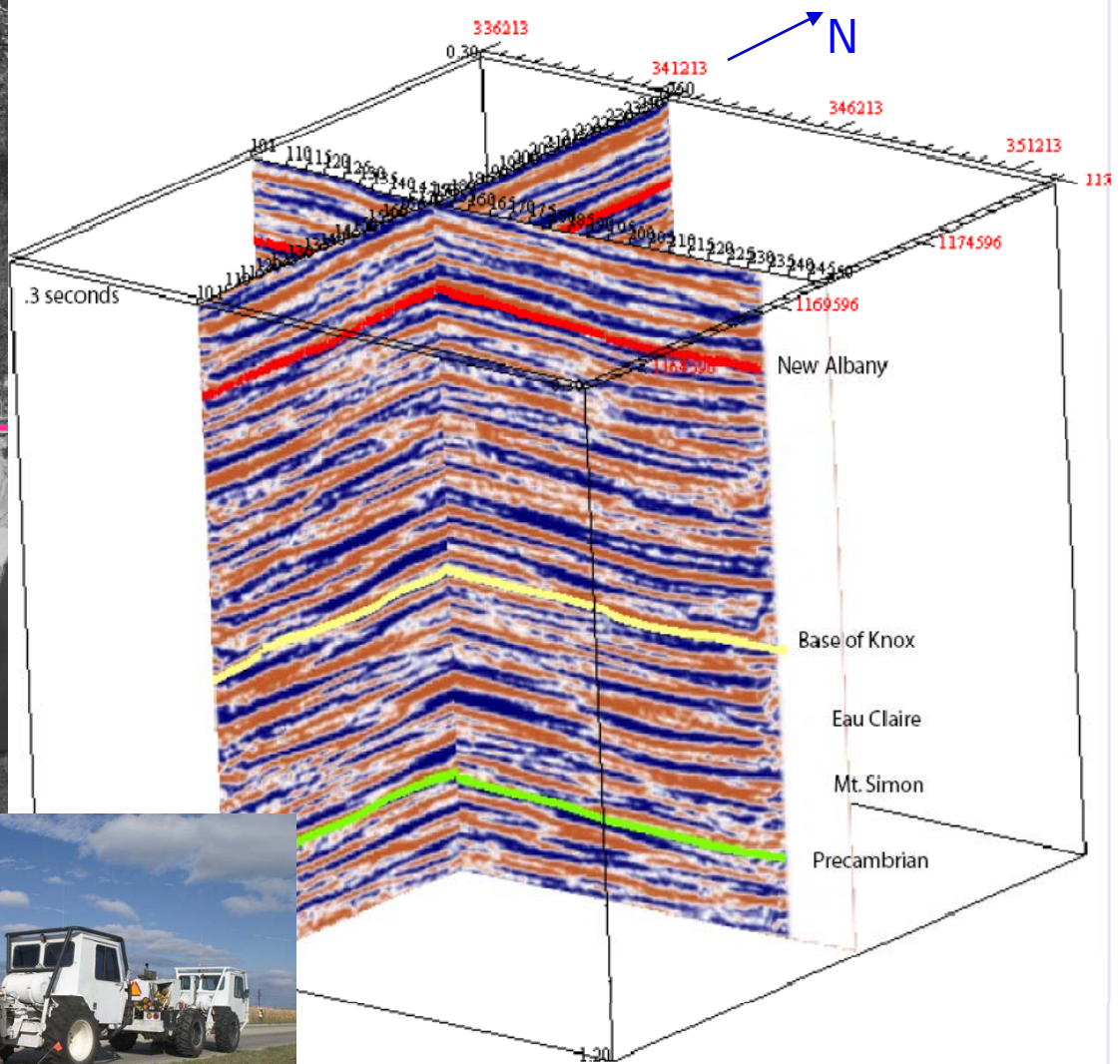
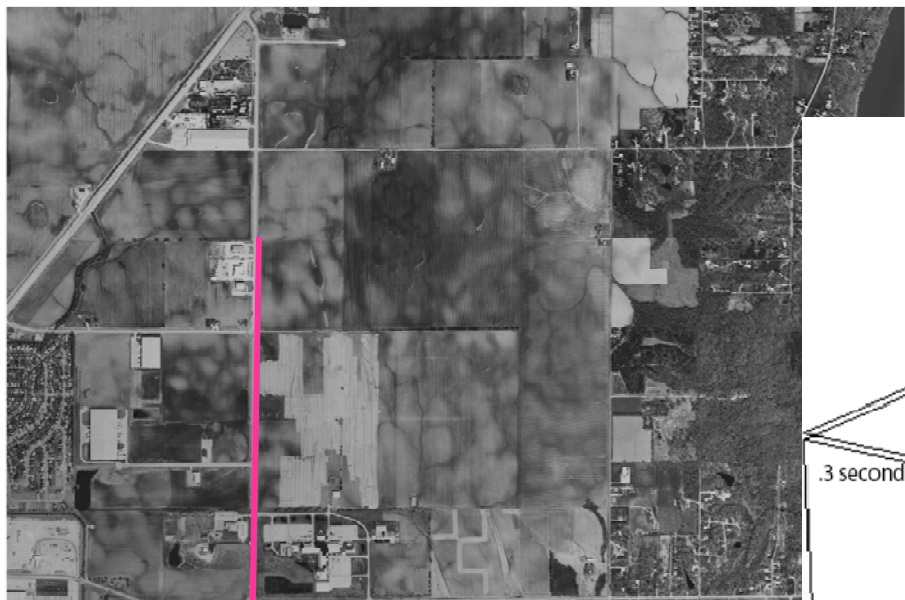
Test site geology at Decatur, Illinois



Decatur, Illinois Location

- Decatur, IL is located in central Illinois on the margin of the thickest part of the Mt. Simon Sandstone depocenter
- Regional geology suggest favorable reservoir quality and adequate seals and backup seals

ADM 2D Survey



October 07

The physical set up at the test site



ADM Test Site

An aerial photograph of an industrial facility, likely a refinery or chemical plant. The image shows various structures including large white storage tanks, a large white rectangular building, and several smaller buildings. There are also large green ponds or lagoons. A yellow rectangular box is drawn around a specific area in the upper left, labeled 'ADM Test Site'. A blue double-headed arrow is drawn across the lower portion of the image, indicating a distance of approximately 3/4 mile between two points.

~ 3/4 mile

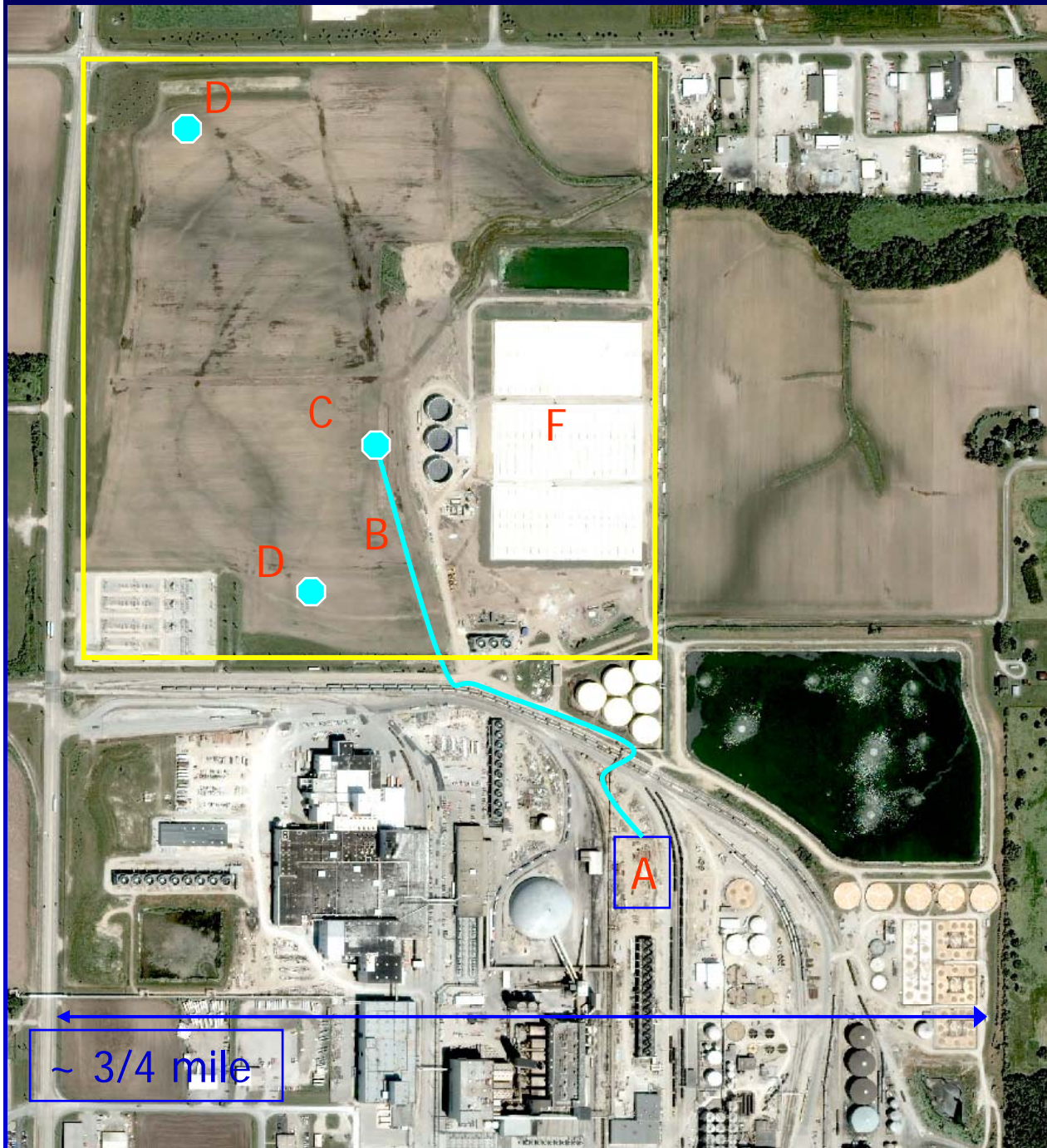
View Southwest Across ADM site



View West-northwest Across ADM site



What about the delivery of the CO₂?

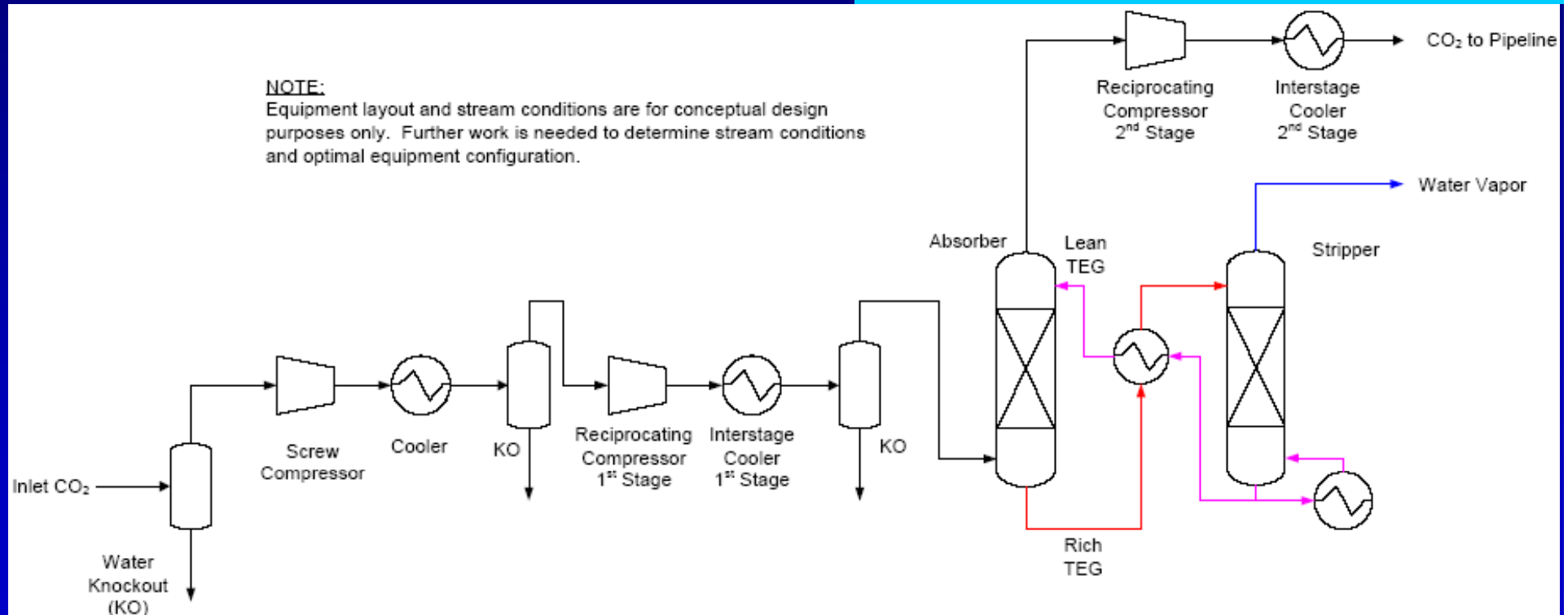


ADM Test Site

- **A** Dehydration/ compression facility location
- **B** Pipeline route
- **C** Injection well site
- **D** Representative verification well sites
- **F** Anaerobic wastewater treatment facility

Preliminary CO₂ Process Flow Diagram for ADM Site

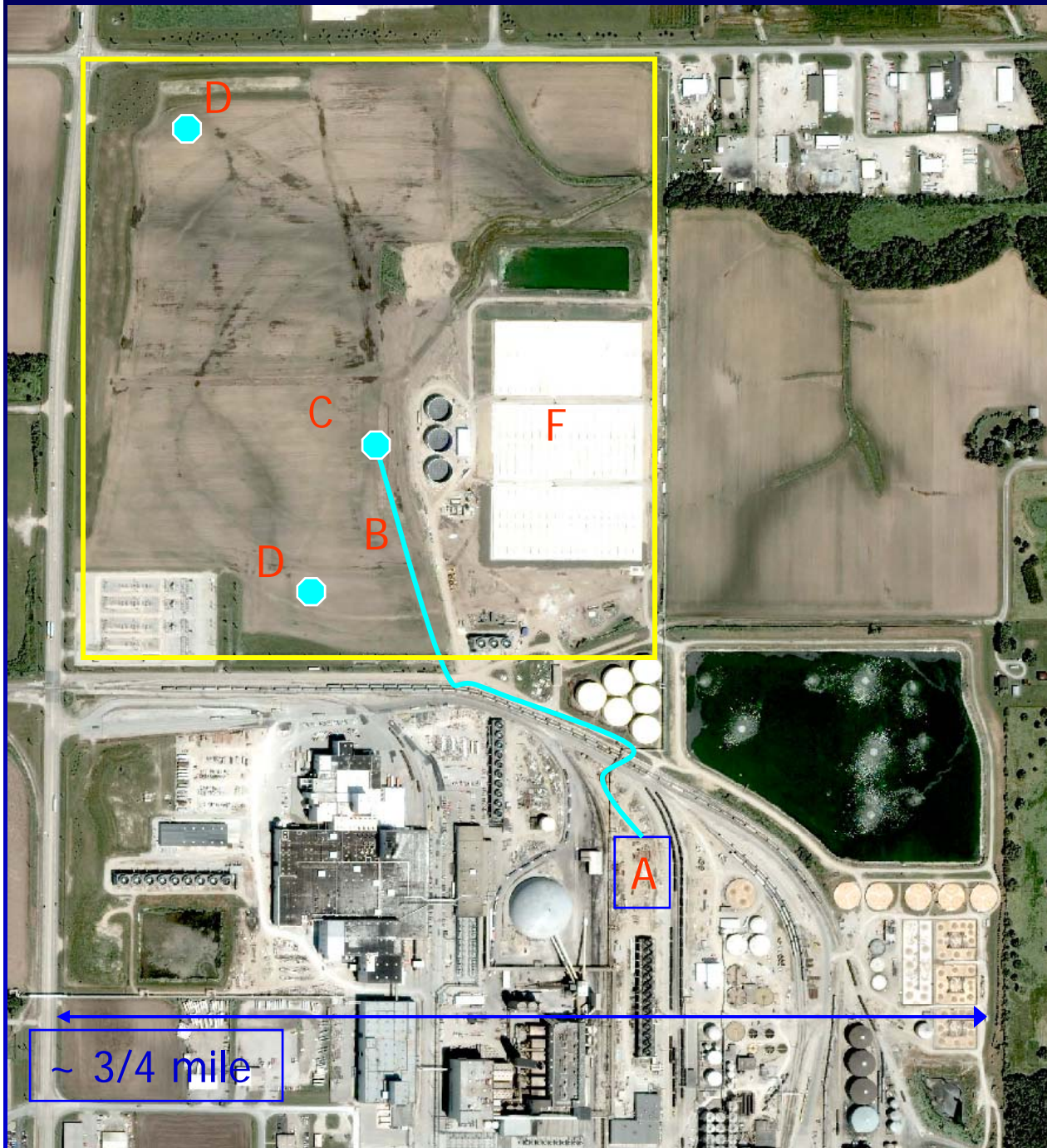
Output
Dry at ~1,300-1,500 psia



Input
Wet at 14.5 psia

from Trimeric Corporation

CO_2 – Where will it go and how do we
check on it?

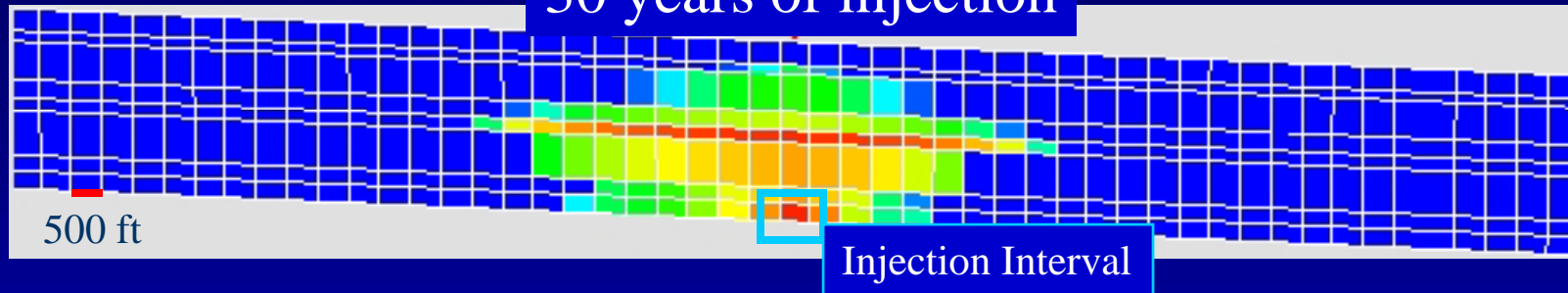


ADM Test Site

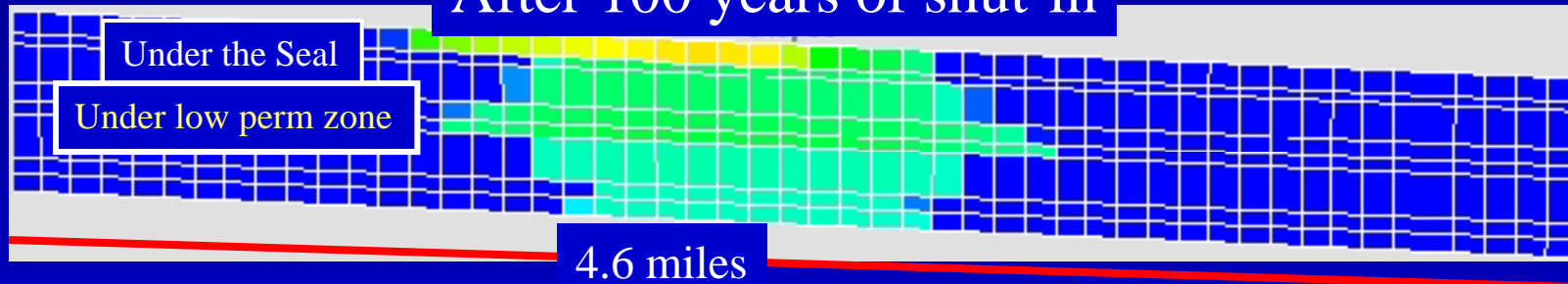
- **A** Dehydration/ compression facility location
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Injection into the Weaber-Horn 1-degree Dipping Beds

30 years of injection

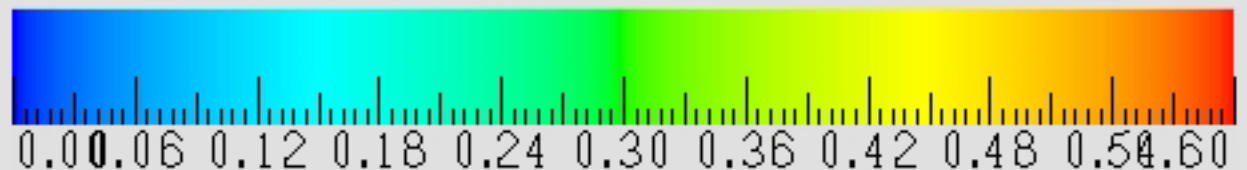


After 100 years of shut-in

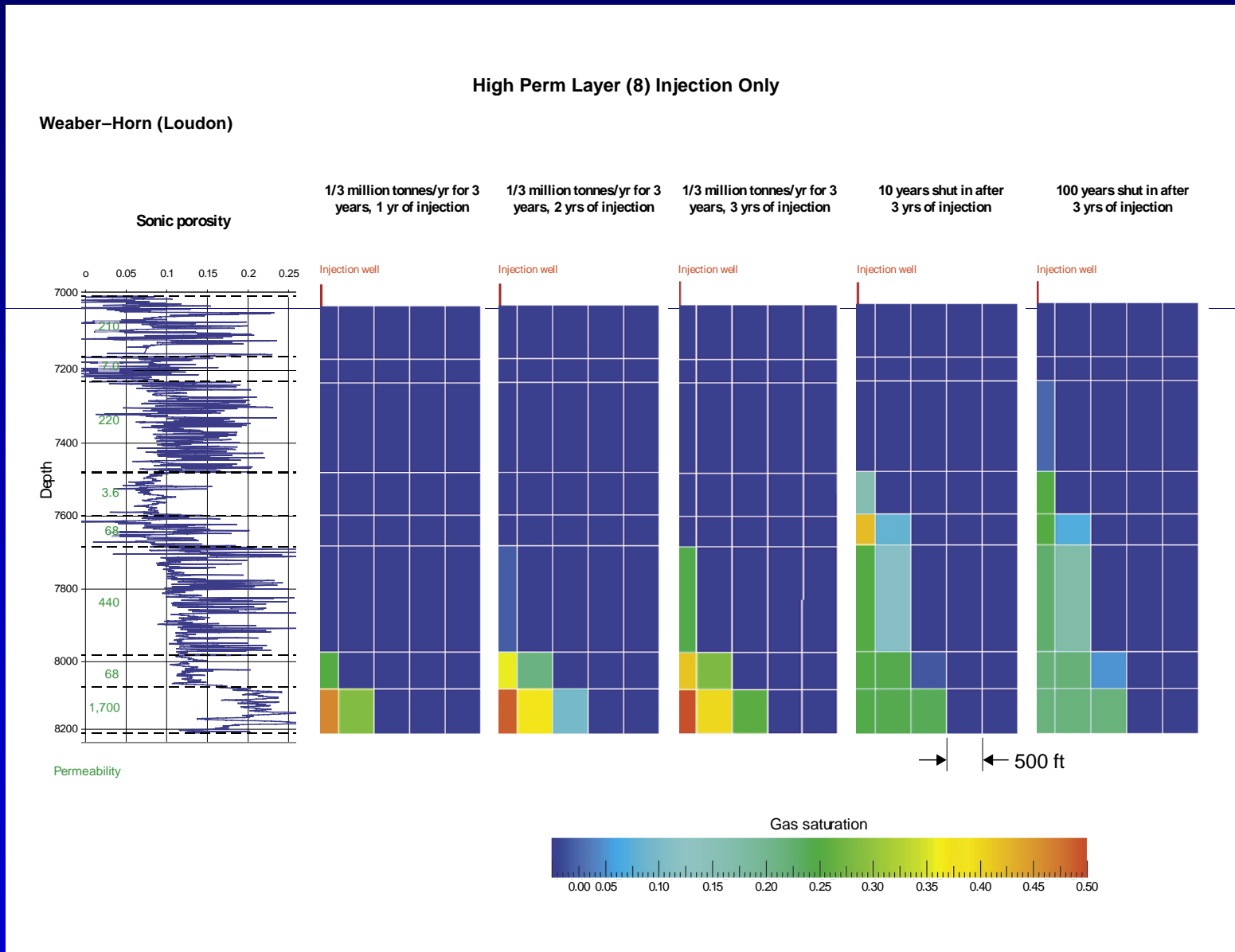


1 million tonnes per year injection

GRID BLOCK GAS SATURATION[SG] (FRACTION)

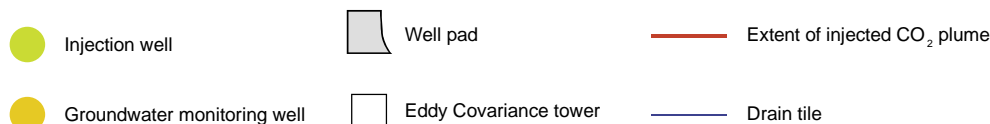
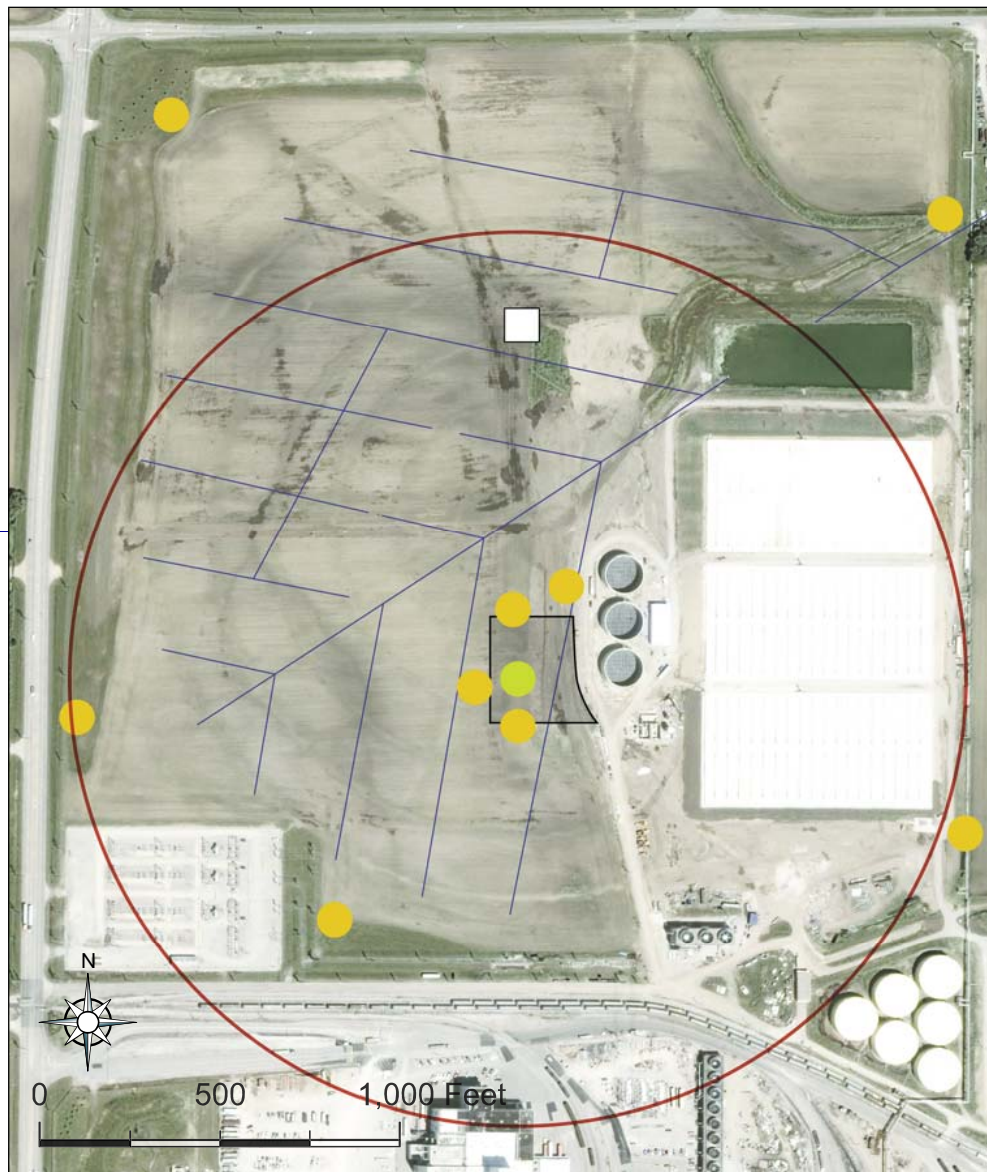


Simulation of CO₂ Injection into Mt. Simon at ADM Site

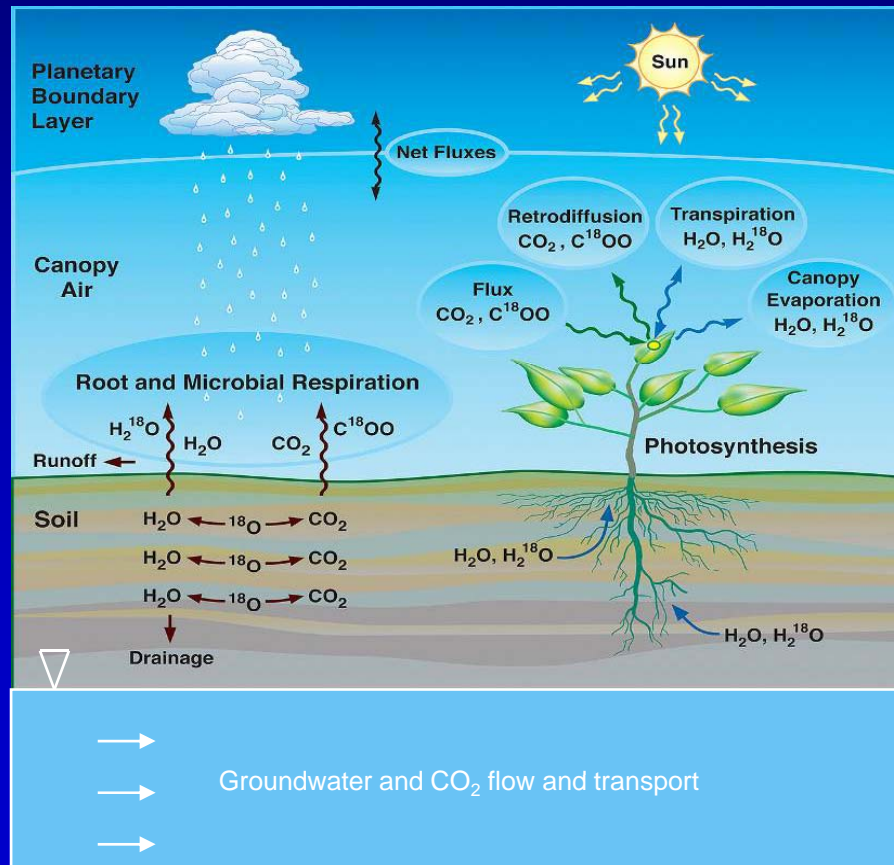


Basic Near-Surface Site Monitoring Plan

- Shallow ground water wells
- Instrument the drain tile system
- Electrical resistivity near injection well
- Surface flux chambers
- Atmospheric monitoring



Surface Monitoring of Air and Soil for CO₂



IR Gas Analyzer

Sonic anemometer



from Oldenburg, LBNL

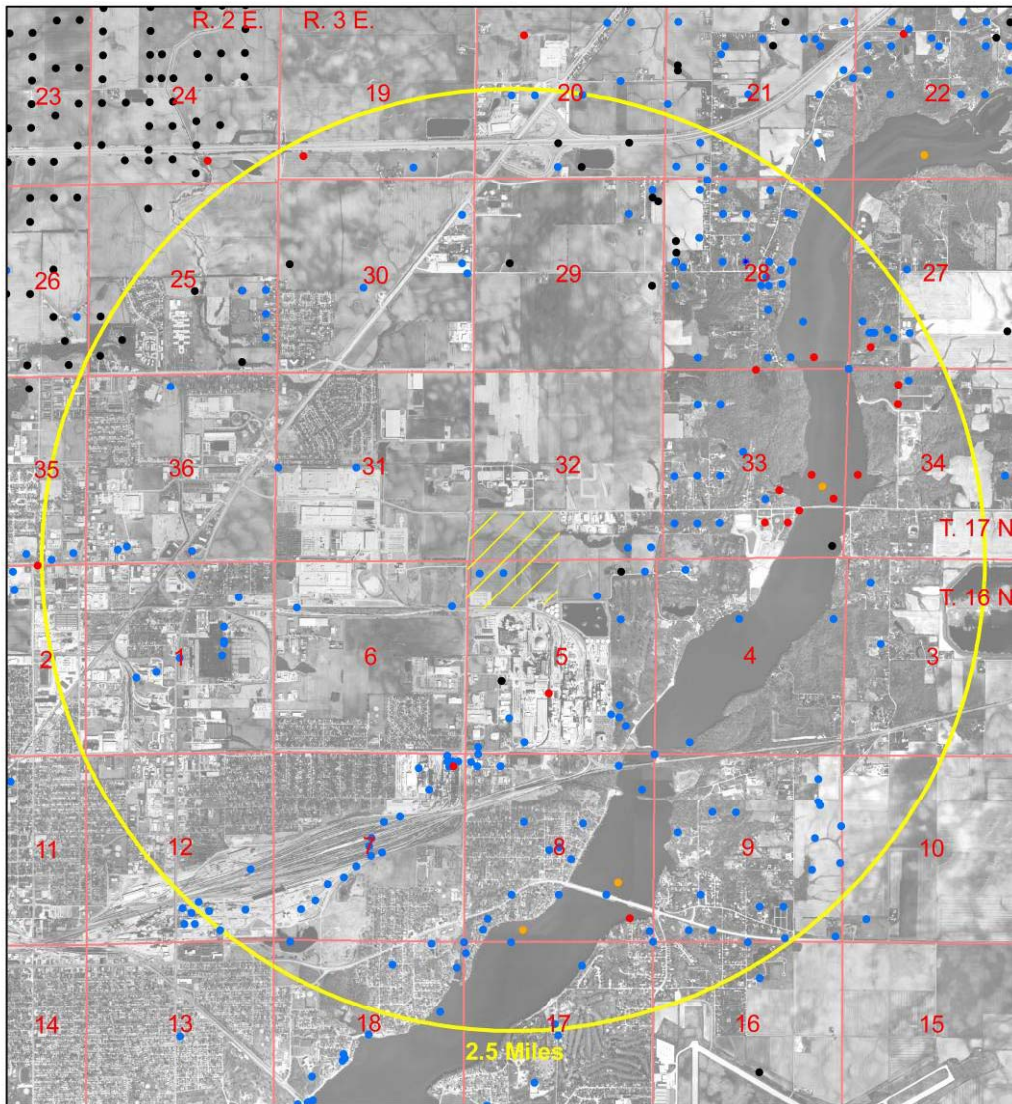
Shallow Groundwater Monitoring



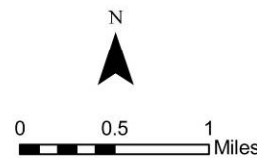
Wells drilled and
periodically
sampled

Wells Near ADM Site

- 2.5 mi radius area of review
- Some existing wells may be adapted to monitoring program



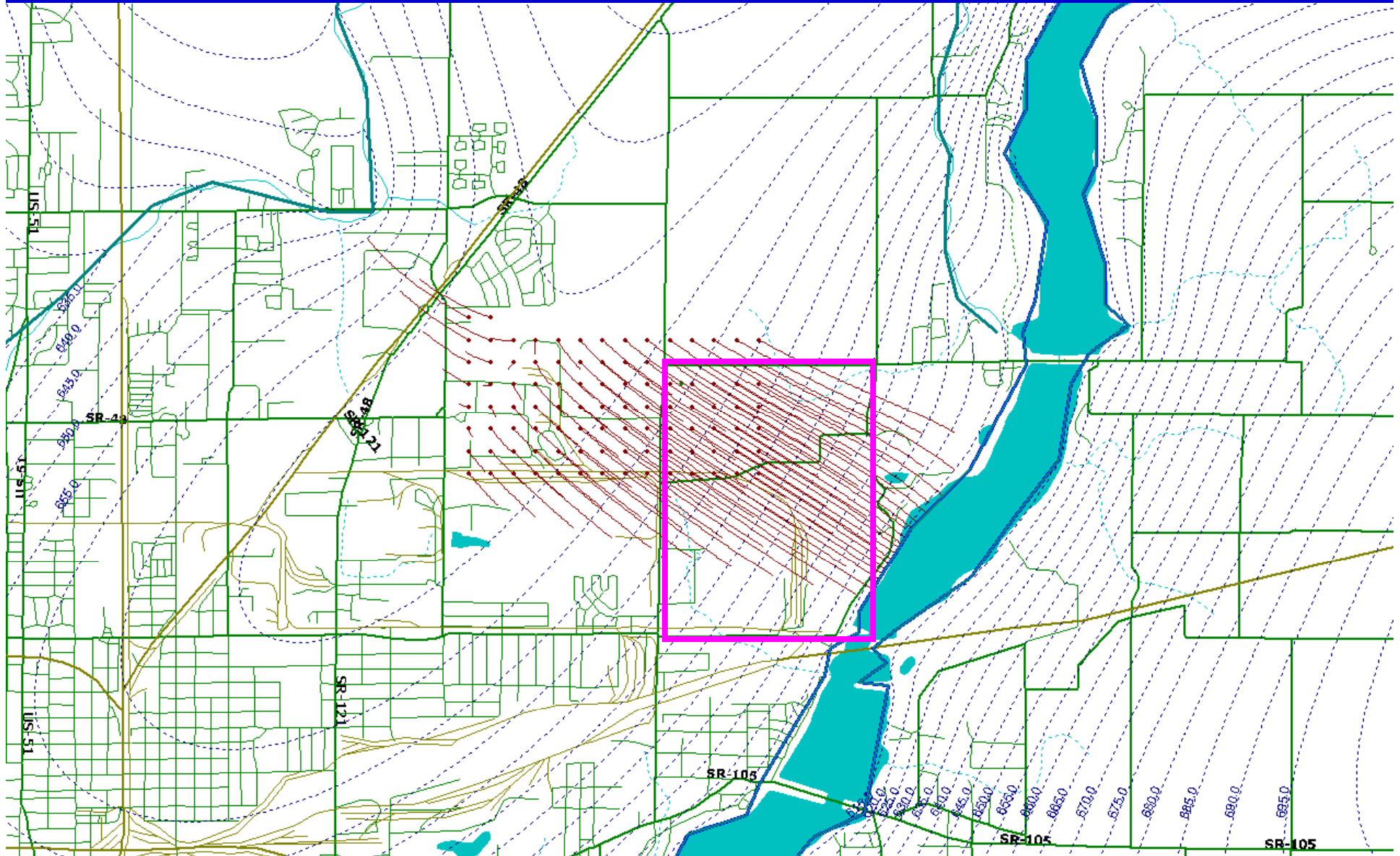
- Water Well
- Oil Well
- Stratigraphic Test
- Engineering Boring



Scale 1:48,000

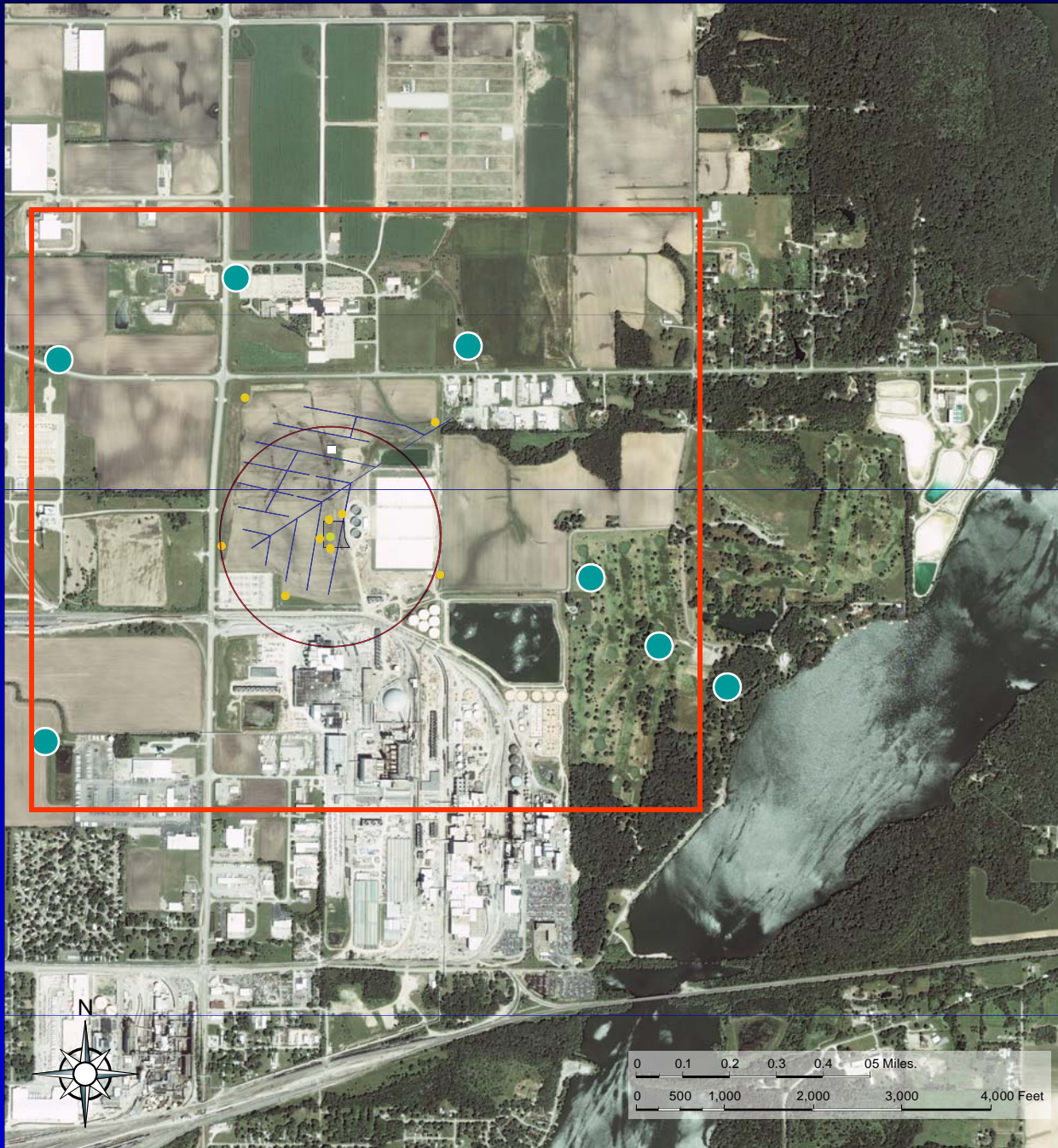
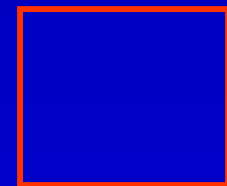
Wells and borings near MGSC Phase III ADM Site, Decatur, IL.
Yellow circle shows a 2.5-mile radius from the center of the property.

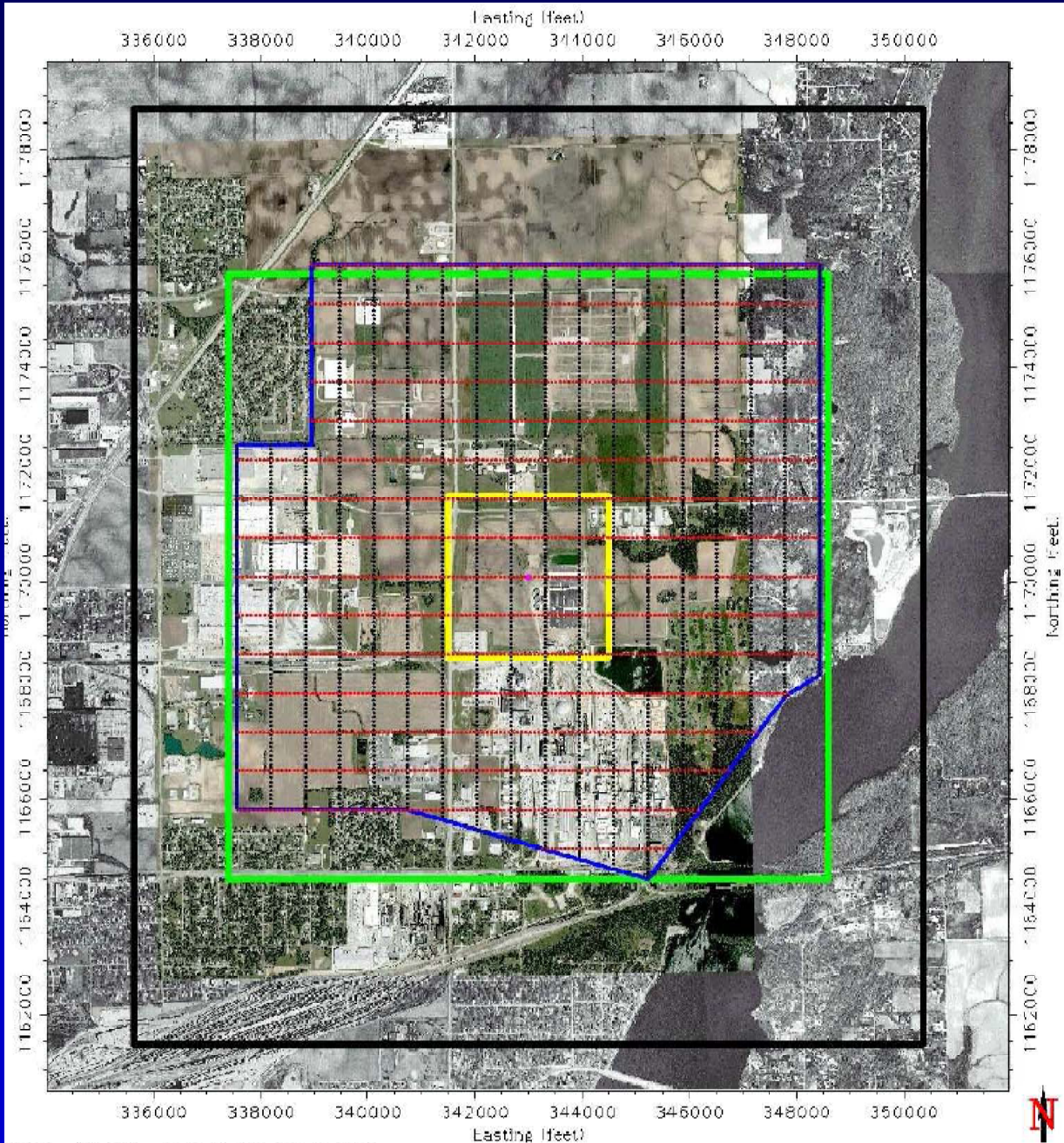
Predicted Shallow Groundwater Flow— Particle Tracking



Area Monitoring

- Shallow ground water well ●
- CIR satellite imagery





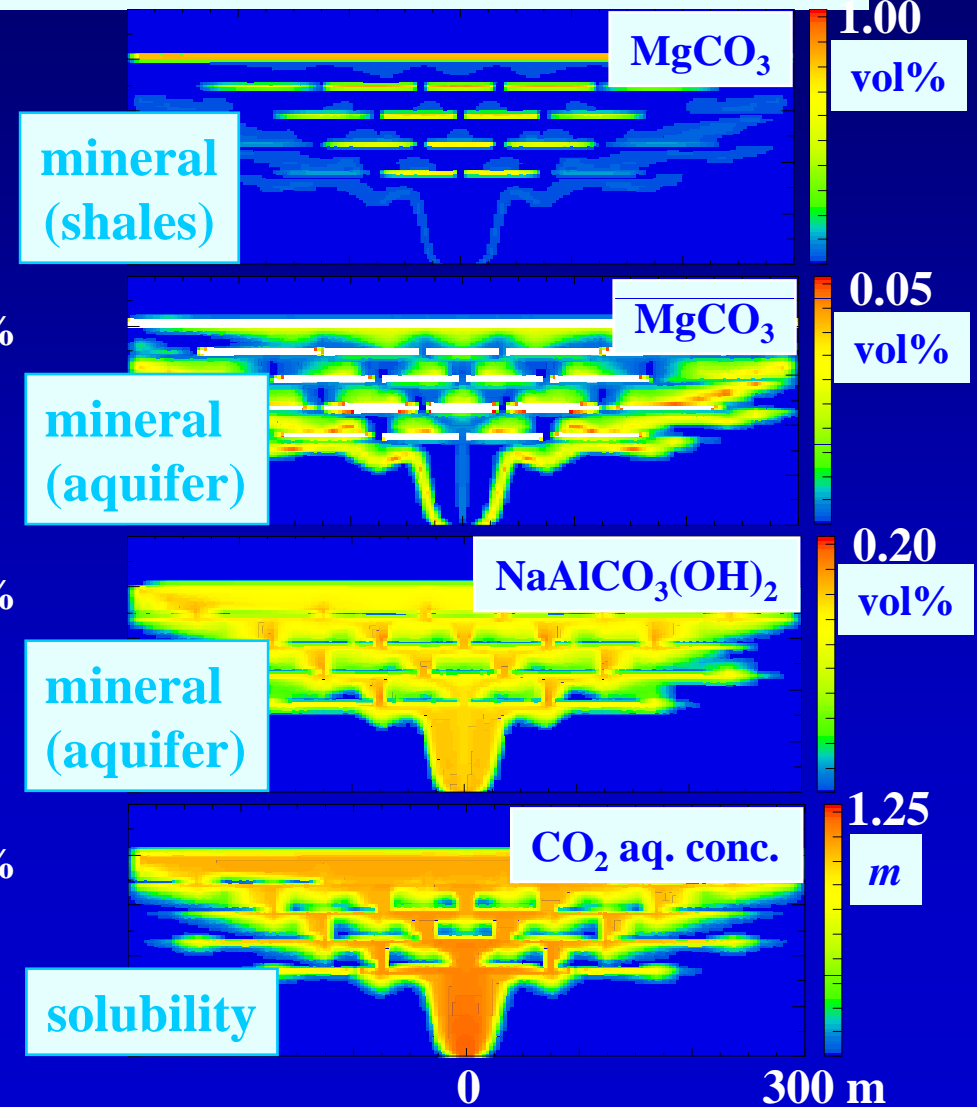
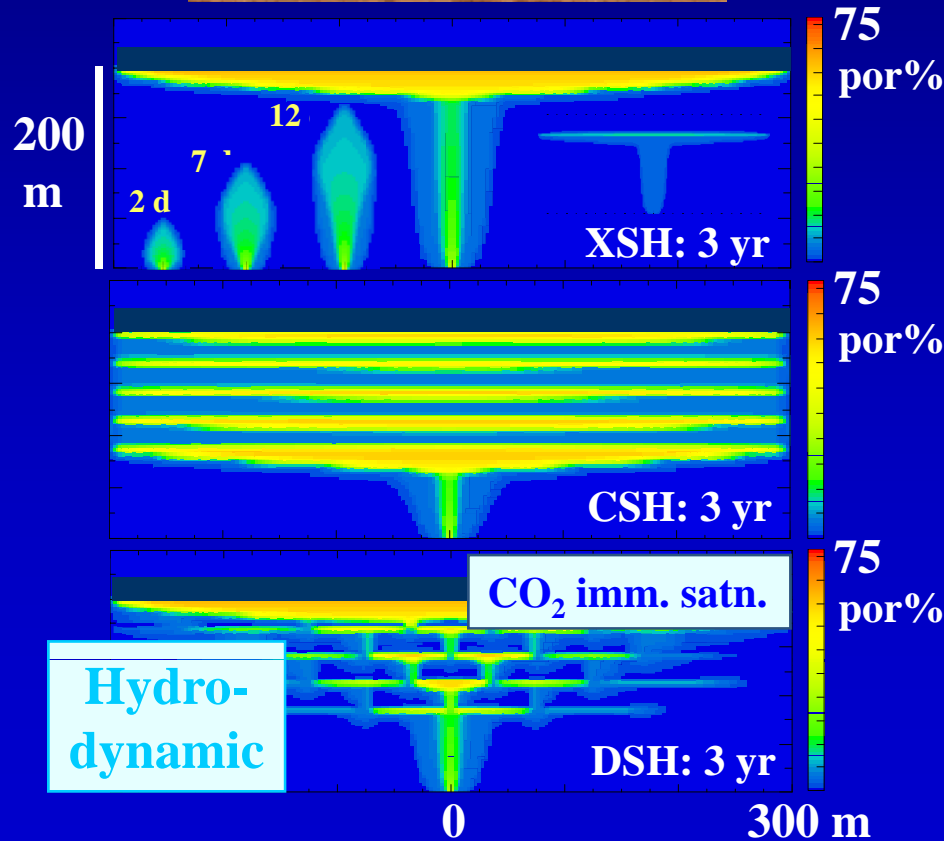
Baseline 3D Design

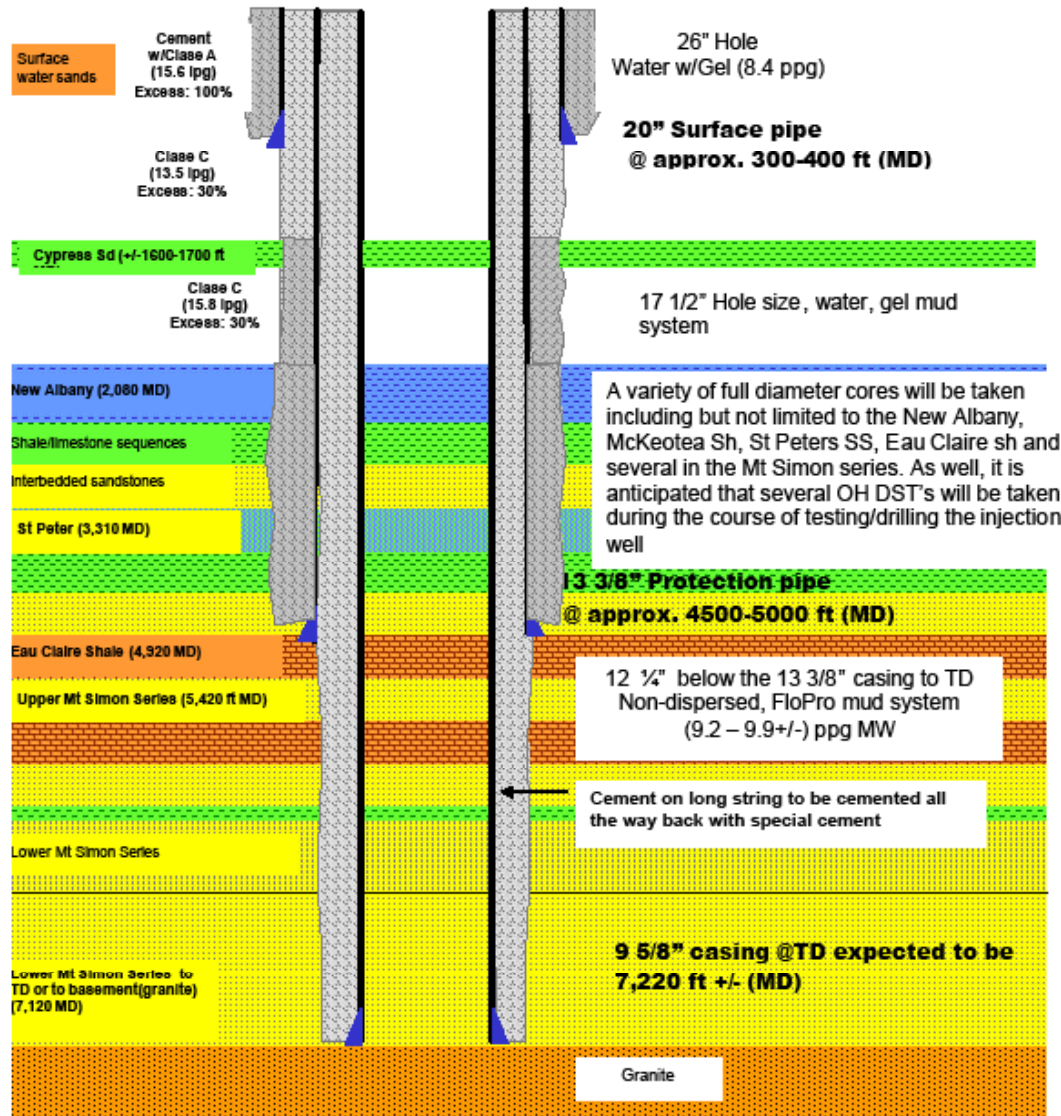
- Migration aperture (green) for full fold of site (yellow)
- Surface use will limit some source (red) and receiver (black) locations
- 40 x 40 ft bins
- 80-fold coverage
- Concurrent VSP

Reactive Transport Modeling of Sequestration Partitioning at Sleipner (Johnson et al., 2002, 2004b)



trapping mechanisms (DSH: 20 yrs)



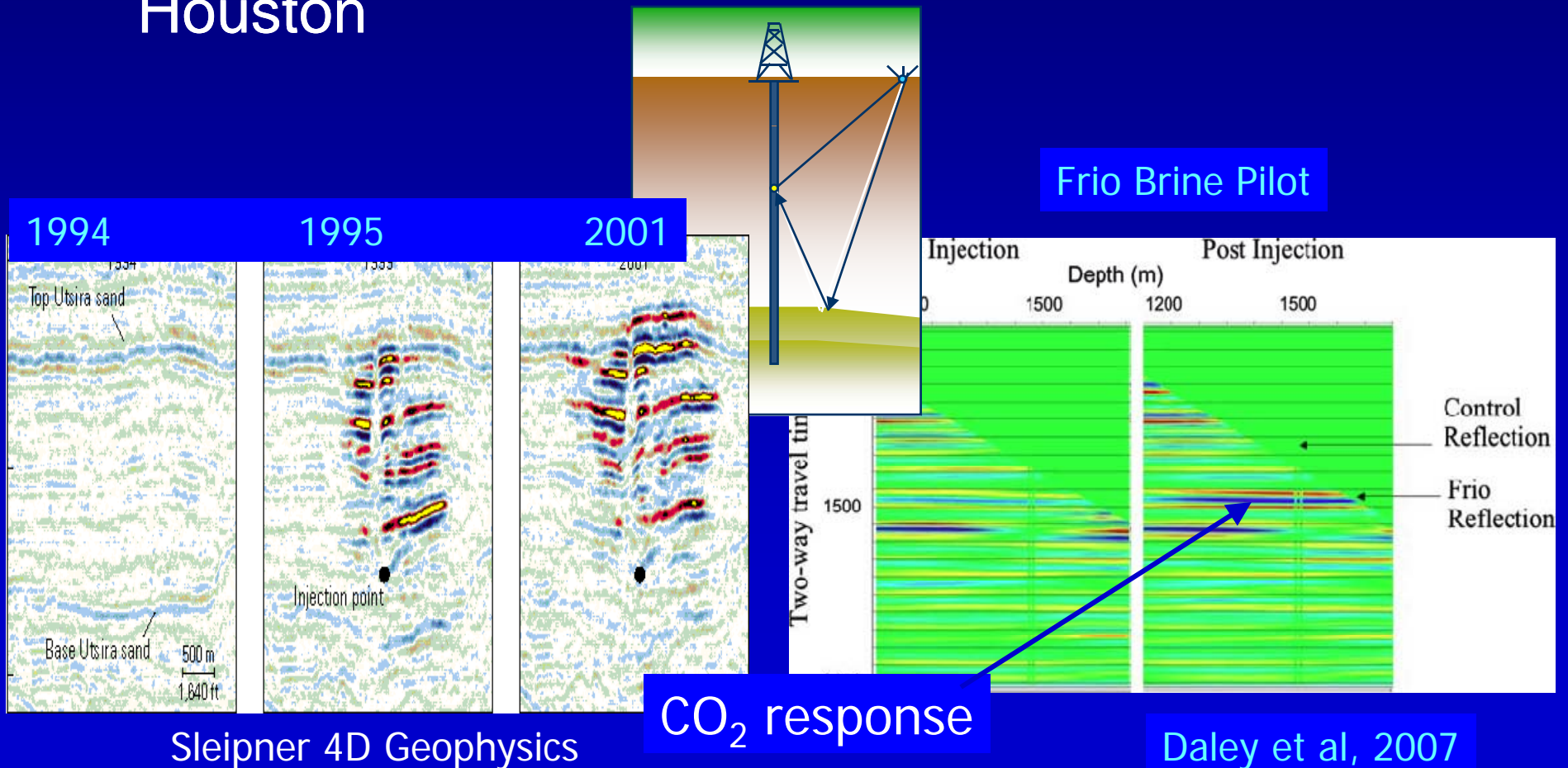


Wellbore Schematic

- Well logs, whole core, fluid sampling, sidewall cores before setting pipe
- Cement to surface in both intermediate and long strings
- Chrome steel casing in Mt. Simon and Eau Claire

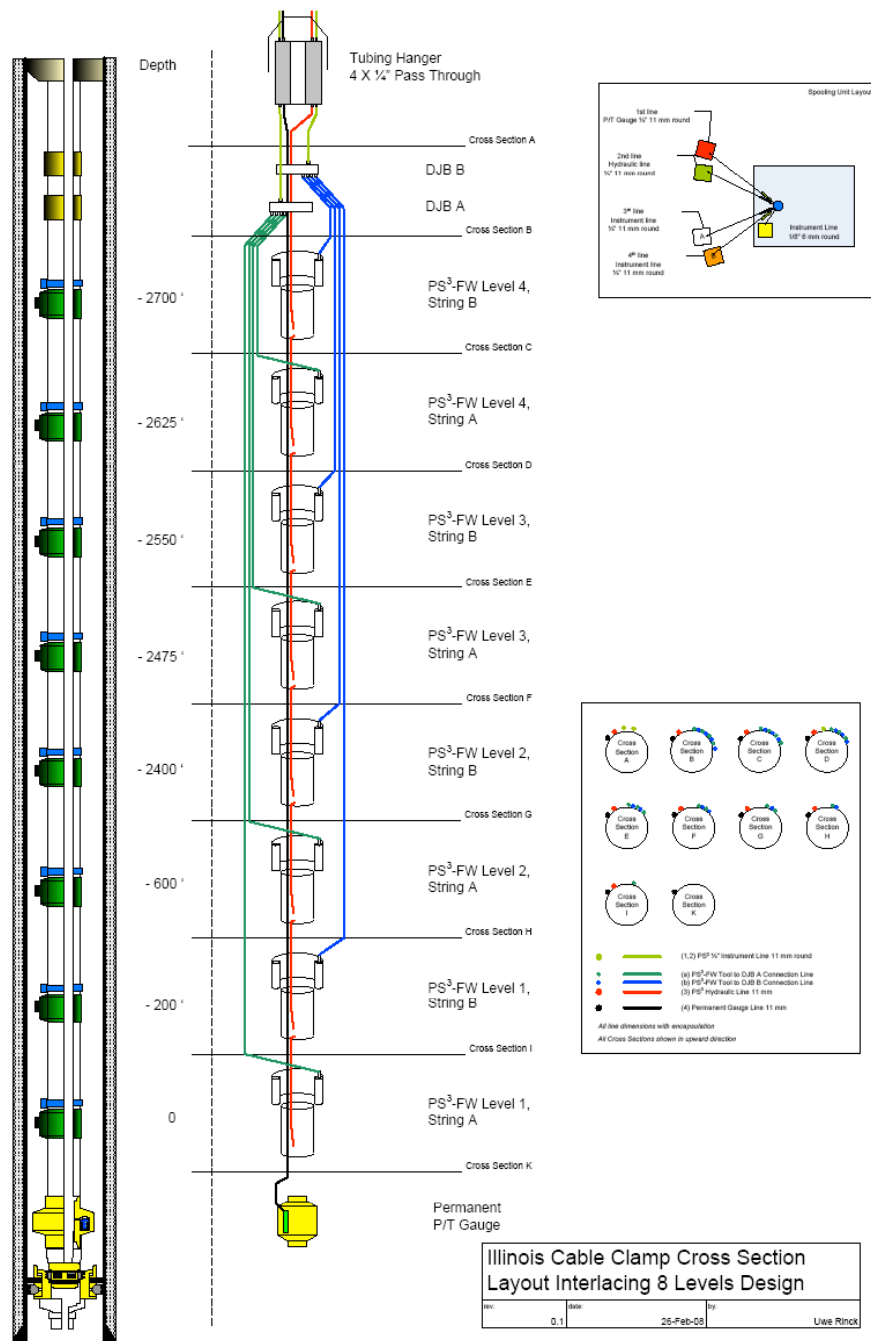
Plume Monitoring Strategies

- Position of CO₂ plume based on repeat surface and downhole geophysics similar to Sleipner project in Norway and Frio Brine Pilot near Houston



8-Level Array

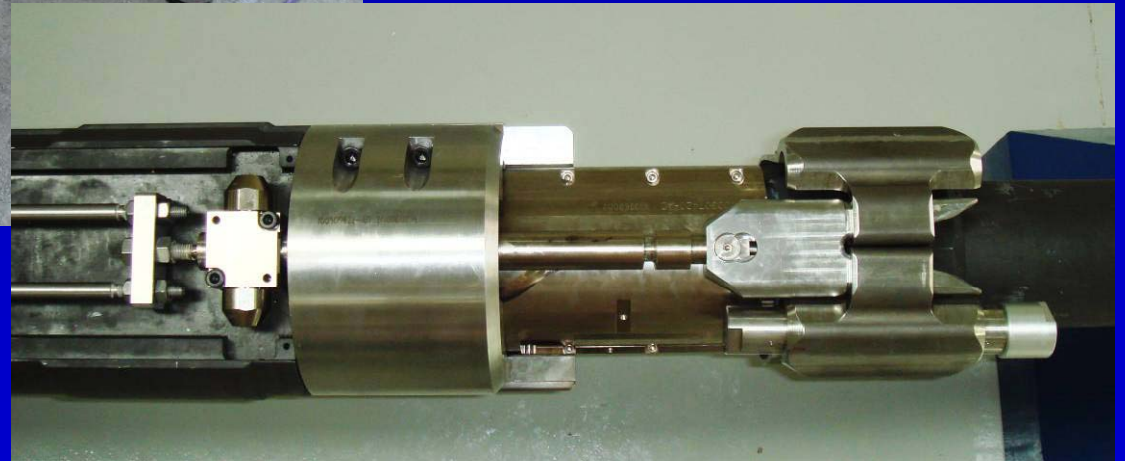
- Cables interlaced to help avoid loss of adjacent sensors
- Sensors close enough to perforations for microseismic monitoring



VSP and Microseismic Sensors

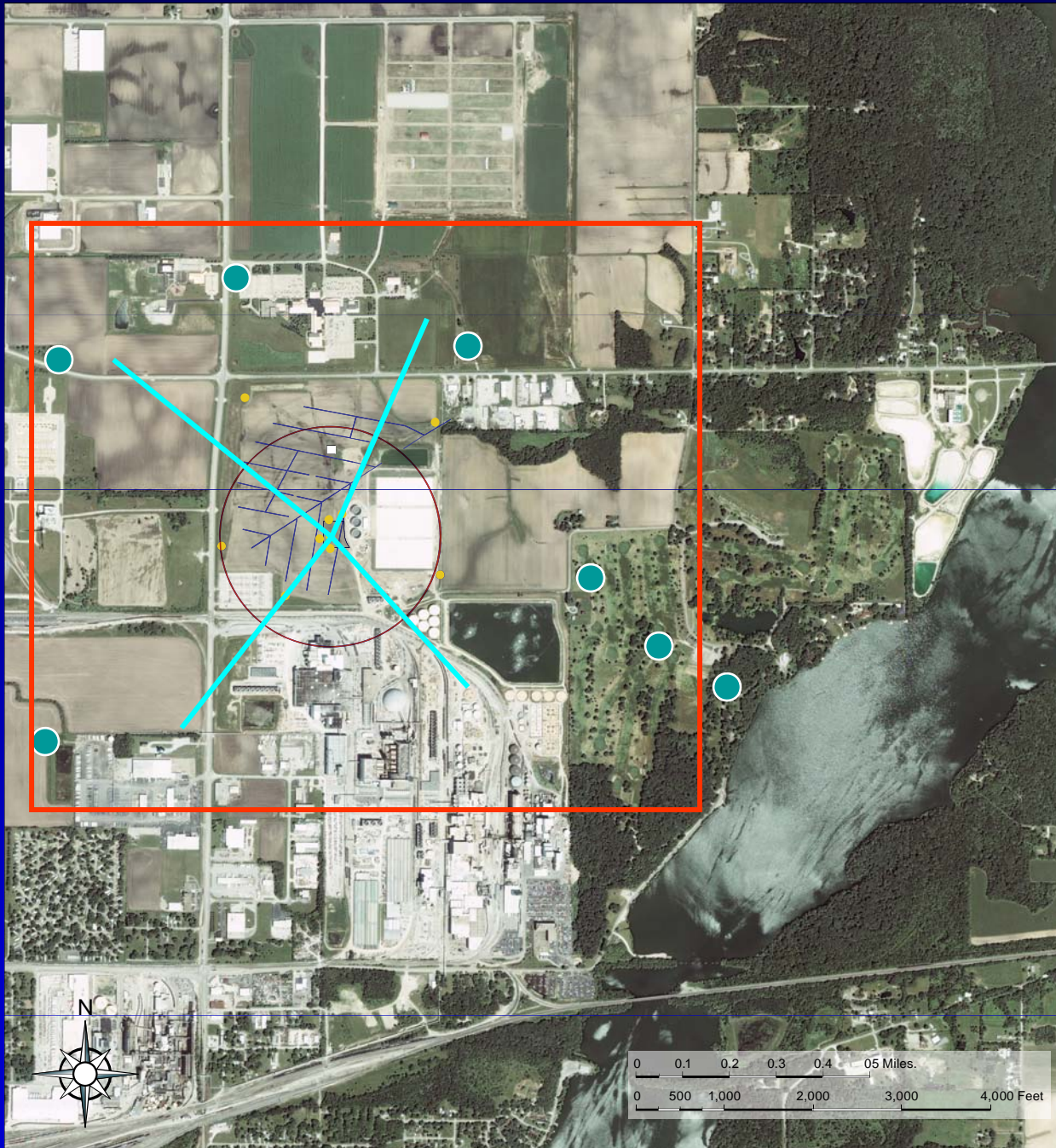
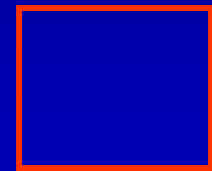


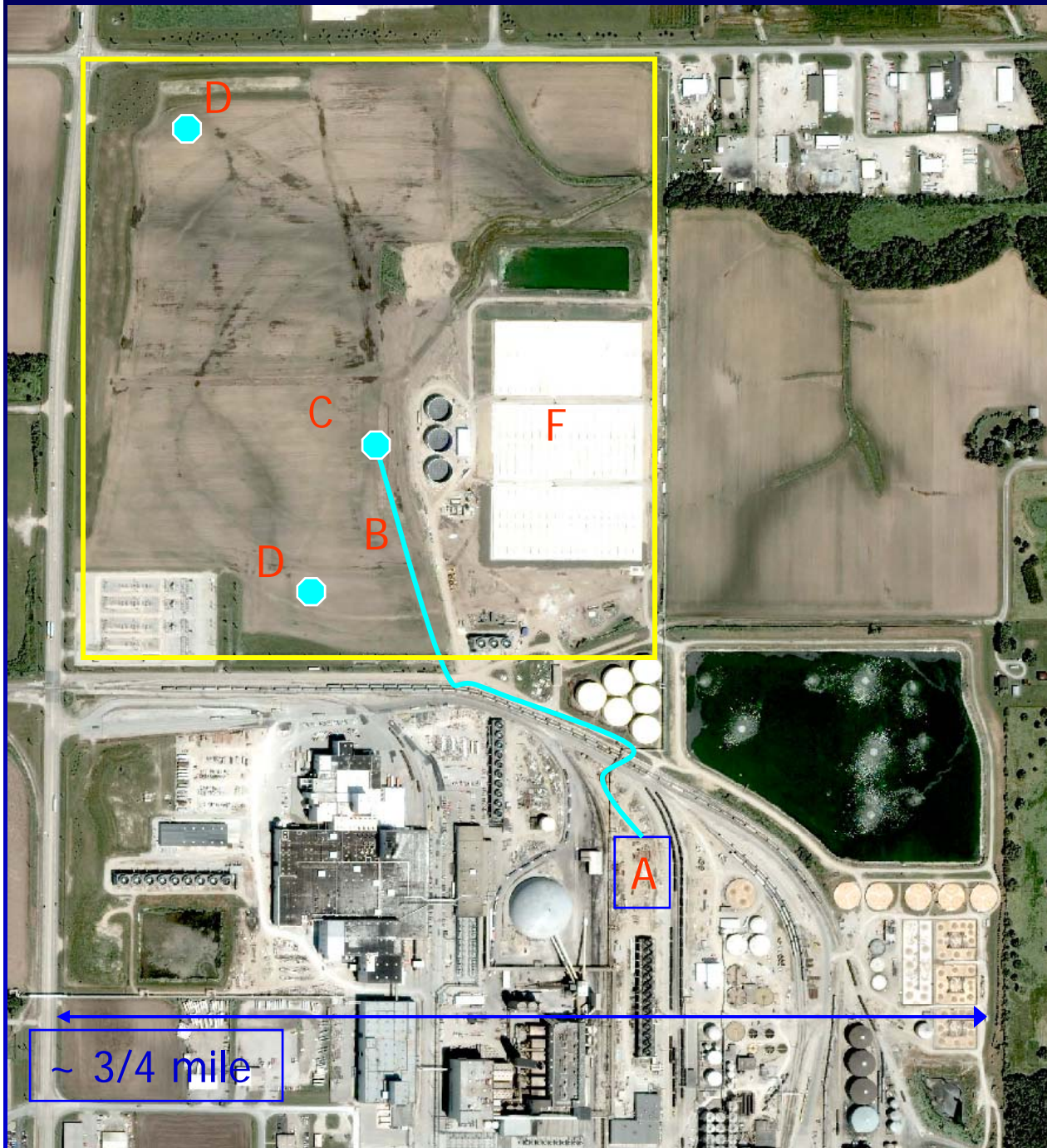
- Sensors tested as run in the hole
- Tubing-conveyed geophones are deployed hydraulically



Area Monitoring

- Shallow ground water ●
- CIR satellite Imagery
- Radial repeat vertical seismic profiles



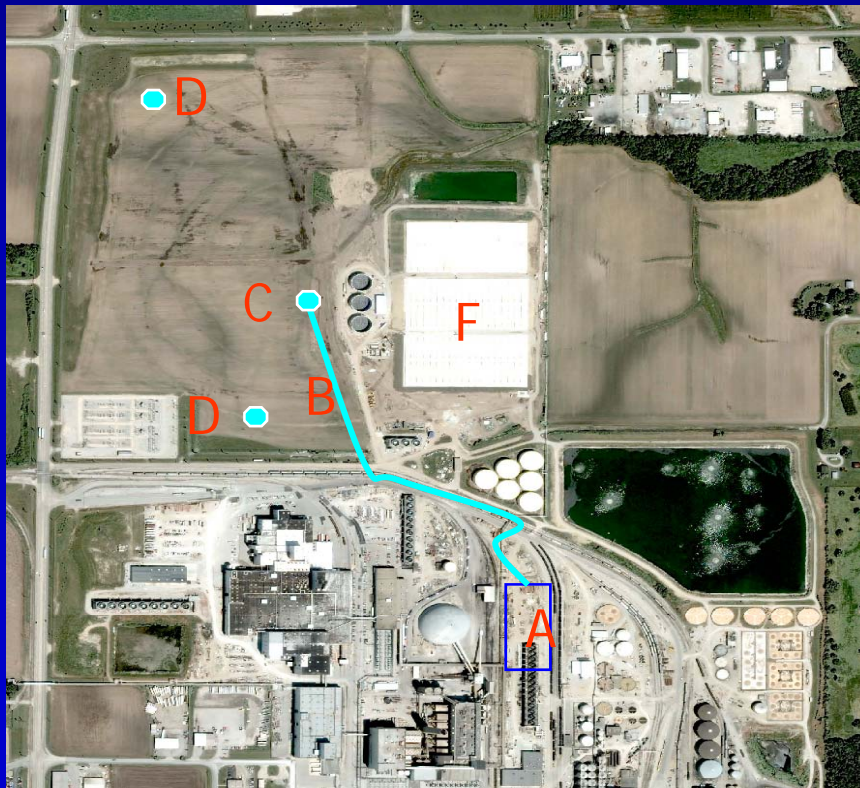


ADM Test Site

- **A** Dehydration/ compression facility location
- **B** Pipeline route
- **C** Injection well site
- **D** Representative verification well sites
- **F** Anaerobic wastewater treatment facility

Plume Monitoring Strategies

- Drill two verification wells (D) based on surface seismic and VSP data, generally one updip and one downdip, or placed based on VSP plume boundary imaging



- Open-hole logging and flexible (Westbay) fluid sampling strategy
- Pressure/temp. monitoring
- Cased-hole logging



Expected outcomes

What are the Phase III outcomes?

- A large-scale injection of 1 million tonnes of CO₂ successfully demonstrated and associated safety, efficiency, and effectiveness requirements met
- Volume sufficient to monitor geophysically; overall effort scalable to IGCC
- A process model established for characterization permitting, equipment, injection, environmental monitoring, and outcome assessment that will support energy facility development with integrated carbon sequestration in the Illinois Basin, nationally, and globally
- An “active” geological site model developed and continually updated as new data are acquired

Outreach

- ADM Partnership building and project coordination
 - Public information session to announce Phase III and inform public
 - On-site visits during well construction
- MGSC Partnership Meetings
 - Joint effort by Illinois, Indiana, and Kentucky Geological Surveys initiated January 2008
- Distribution and Creation of Materials
 - Posters
 - Video
 - Interactive sequestration animations
 - Fourth Edition of Model Created – working toward production and availability
- Complete Website Redesign

Education

- Developing teacher workshops
 - Situated to benefit the Phase III local and regional community
 - Laying the groundwork for programs in the Decatur school district
 - Illinois Basin region
- Earth Explorers Program in Decatur, Illinois – January 2008
 - Program designed to support local elementary school teachers
- Hosting Keystone Climate Change Workshop in August 2008
 - Bringing in teachers from Illinois, Indiana, and Kentucky
- Partnering with University of Illinois to provide content courses for Math Science Partnership In-Service Master's Degree program for teachers
- Richland Community College – initial meeting planned for April 2008

Risk Management and Safety

- FEP- base risk analysis led by SCS with 2 rounds and 27 evaluators
- 77 FEPs being ranked

-25 to -20	BLACK	NON-OPERABLE: Evacuate the zone and or area/country
-16 to -10	RED	INTOLERABLE: Do not take this risk
-9 to -5	YELLOW	UNDESIRABLE: Demonstrate ALARP before proceeding
-4 to -2	GREEN	ACCEPTABLE: Proceed carefully, with continuous improvement
-1	BLUE	NEGLIGIBLE: Safe to proceed

MITIGATION Control Measures		LIKELIHOOD				
		Improbable 1	Unlikely 2	Possible 3	Likely 4	Probable 5
SEVERITY	Light -1	-1 1L	-2 2L	-3 3L	-4 4L	-5 5L
	Serious -2	-2 1S	-4 1S	-6 3S	-8	-10
	Major -3	-3 1M	-6 2M	-9 3M		
	Catastrophic -4	-4 1C	-8 2C	-12 3C		
	Multi-Catastrophic -5	-5 1MC	-10 2MC	-15 3MC		

White arrow indicates decreasing

RISK REGISTER - MGSC Phase III

wellsite SURFACE

traffic, security, buildings, surface data acquisition, pits/cuttings/waste, office space, wildlife, wellhead, utility corridors, personal exposure (weather, fumes), soil contaminants, etc

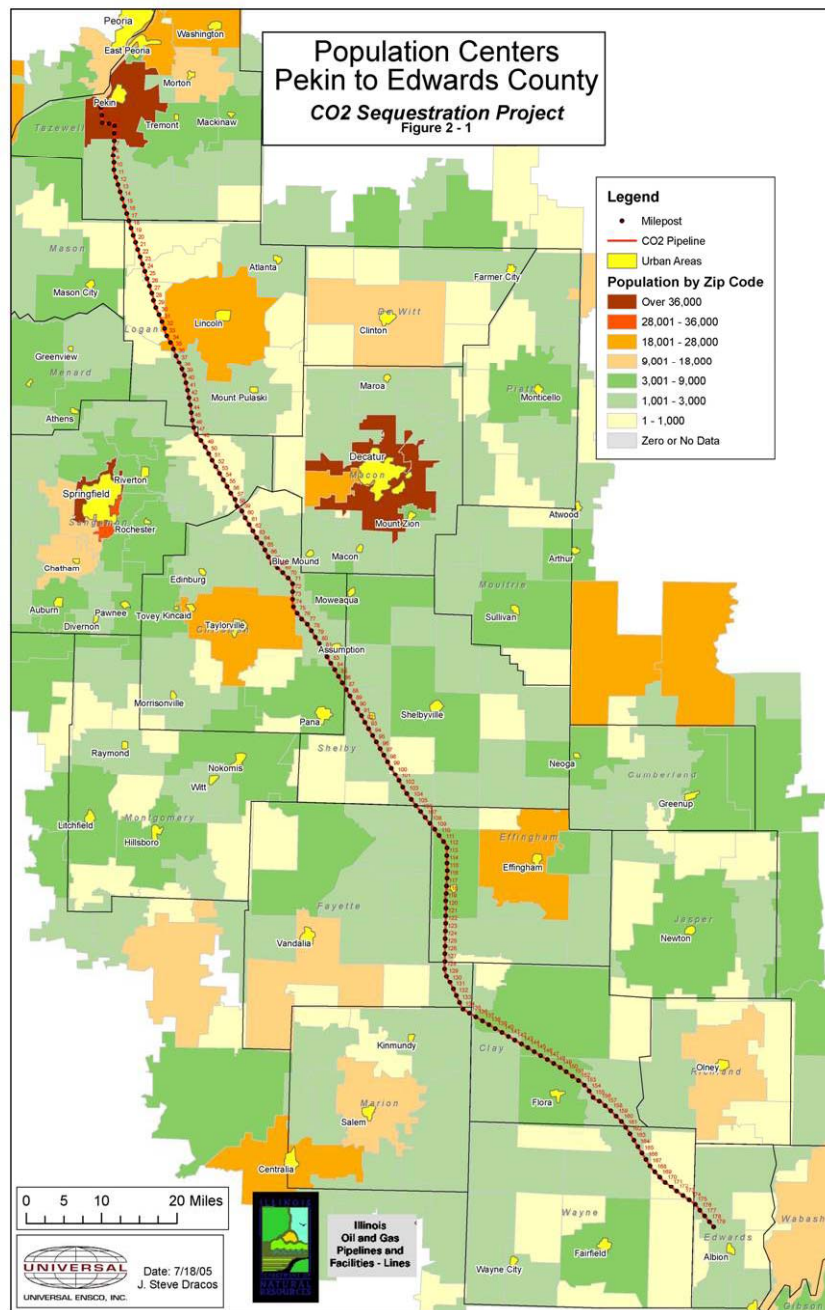
			DATA ENTRY COLUMNS							
			Allowed: 1,2,3,4,5; L,S,blank				Any text.			
ORDER	FEP Item (risk element)	Project-specific information about FEP-related risk	L LB	L Best Guess	L UB	S LB	S Best Guess	S UB	NOTES Highest L*S Scenario, most at- risk Values.	L*S
1	Bolide impact	Bolide impact could cause total CO2 release.	L	L	L	s	S	s		#VALUE!
2	Erosion and deposition	The ILADM project area is flat to rolling, and is unlikely to undergo erosion or deposition affecting project operations or longterm storage.	L	L	L	s	S	s		#VALUE!
3	Accidents and unplanned events	Surface operations, including those related to ADM industrial operations, could expose personnel, wellhead, wellbore, and image to risks.	L	L	L	s	S	s		#VALUE!
4	Soils and	Where not occupied by buildings, the ILADM area is largely agricultural.	L	L	L	s	S	s		#VALUE!

- HSE plan
- Pre-drill exercise

Challenges and problems

Things that Impact Plans, Schedules, Costs, and Manpower

- Permit - timing, precedents
- Rig schedule and availability
- Cost (and availability) of tubulars and services are major concerns as energy industry demands/costs continue to rise
- Staffing



Transportation

- 180 mile pipeline
- 365 MMscf/d (7.7 Mtonnes/yr) designed pipeline from a “CO₂ EOR” perspective
- Medium pressure (2,300 psig) 18-inch pipe, cost estimate is \$779,444/mile (2004\$)
- \$144 million installed
- Illinois studying pipeline “backbone”



Midwest Geological
Sequestration Consortium
www.sequestration.org